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Bulletin of the Seismological Society of America

PUBLICATION COMMITTEE

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J C Branner

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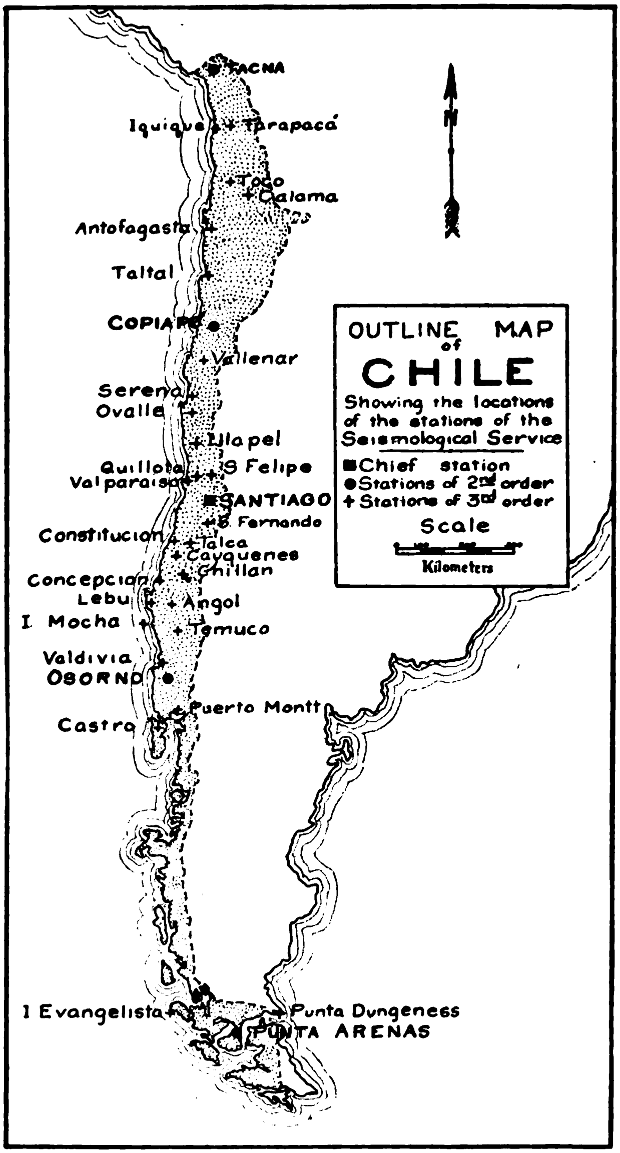
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N
OUTLINE MAP of CHILE
Showing the locations of the stations of the Seismological Service
■ Chief station
● Stations of 2nd order
+ Stations of 3rd order
Scale
Kilometers

The Bulletin of the
Seismological Society of America

VOL. I MARCH, 1911 NO. 1

SEISMOLOGY IN THE UNITED STATES

By Andrew C. Lawson

The issue of the first Bulletin of the Seismological Society of America appears to me to be a fitting occasion for a brief review of the present status of seismology in this country, and for some suggestions looking to the possible improvement of that status.

The great advances in seismology in recent years have been along the lines of instrumental perfection and the interpretation of instrumental records. The wide distribution of modern seismographs in civilized countries has supplied the data necessary for important discussions of the significance of earth vibrations, their rate of propagation and their paths; and these discussions have not only greatly enriched the science of the earth but have drawn many new men to this field of research.

Until within a very few years the United States was far behind many other countries in its equipment for this work and in the number of men interested in it. The list of seismological stations published in another part of this Bulletin clearly shows, however, that we are bestirring ourselves and are preparing to do our share in the study of earthquakes. This awakening interest in the phenomena of earthquakes dates chiefly from the California earthquake of 1906. It is manifested not only in the establishment of seismological stations at various universities and colleges throughout the country, among which the Jesuit colleges are the most notable for the zeal and thoroughness with which they have extended and organized such installations, but also by the establishment of a society wholly concerned with the advancement of this branch of science.

There is an important department of seismology which can be pursued to advantage only by world-wide cooperation. I refer to the instrumental study of earthquakes of the first class or those of such great violence that their vibrations extend to all parts of the earth's surface and may be recorded by suitable apparatus. The exact determination of the time of arrival, intensity of the components of motion and duration of the different phases of these vibrations, at a sufficient number of stations distributed over the face of the earth, affords data of the highest importance for the solution of the problem of the physical condition of the interior of the earth.

In view of our increasing number of observing stations there can be little doubt but that we shall be able in future to contribute more and more to this world-wide cooperation. Indeed, most of the installations of recent years in this country are better fitted for this kind of observation than for the study of earthquakes of smaller magnitude but of greater local importance.

Now, when we stop to review the spread of these installations in the United States during the past few years, we cannot fail to be impressed with the fact that it is due to local spontaneity and that the distribution of the stations is governed by no guiding principle. Their position has been determined by accident rather than by design. For the purpose of a world-wide network of stations equipped primarily for recording shocks of the first class, they are too few in the greater part of the country and possibly unnecessarily numerous in certain other parts where institutions and interested men are not widely spaced. Under existing conditions the disproportion in the spacing of stations is likely to continue and to become more marked by the multiplication of installations where they are least needed. It is evident from this state of affairs that our seismological activities are unorganized. The lack of organization has been fully recognized by the men most interested in the subject, and various attempts have been made to reduce the work to a more systematic and economic basis. It has been proposed, for example, that at certain of the more important stations of the U. S. Weather Bureau suitable seismographs should be installed and placed under the care of the local officers of the Bureau. This proposal was urged upon Congress by a committee of the American Association for the Advancement of Science, and was endorsed by the chiefs of the more important scientific bureaus of the government. The proposal was, however, rejected.

Another appeal was made to Congress to establish a bureau of seismology under the Smithsonian Institution, and altho the suggestion received the approval of a great many scientific men thruout the country, and altho the subvention asked for in support of the bureau was not more than $20,000, the bill which was introduced for the purpose was killed in committee.

It is clear that if the matter is left to individual initiative or to institutions of local scope that the present unorganized condition of this work is likely to continue. Apparently the only hope for the cure of the evil is that the work should be taken up by a financially strong institution like the Carnegie Institution of Washington.

Another and rather different phase of seismological work and one which has received but little attention in this country is that which is concerned with seismicly active regions. There are several such regions in this country, but the most notable is comprised within the borders of California. In such regions where small earthquakes occur frequently and disastrous shocks occasionally, the proper investigation of the conditions which obtain in the earth's crust necessitates a combination of geological field work with instrumental observations recorded at numerous stations equipped with machines for recording light shocks rather than heavy ones. These numerous stations distributed over such a seismicly active region require the direction of a central station for the region. The work requires a corps of observers who shall give about an hour daily to the apparatus and the forwarding of reports to the central station. It requires also a small number of active field geologists who are specialists in structural and physiographic geology. Such an equipment of stations and men can only be secured by an expenditure of the necessary money for installation, maintenance and salaries. The work thus organized would result in not only the precise location of all the various faults which by recurrent movement produce earthquakes within the region, but it would also enable us to become familiar with the progress of fault movements and so contribute very greatly to geological science.

For such an undertaking, having to do with natural conditions and processes which affect humanity so seriously, it might be supposed that funds would be readily forthcoming. But such is not the case. In the present state of public opinion in California for example, it is practically impossible to secure state aid for the study of earthquakes. The commercial spirit of the people fears any discussion of earthquakes for the same reason as it taboos any mention of an occurrence of the plague in the city of San Francisco. It believes that such discussion will advertise California as an earthquake region and so hurt business. In this state of public opinion our only hope for the proper prosecution of the study of earthquakes in those regions where their study may be most advantageously undertaken is to have the work carried out by an independent and financially capable institution devoted to scientific work. Again, the mere statement of the situation suggests that the organization and maintenance of this branch of seismology might fittingly be undertaken by the Carnegie Institution of Washington.

A further necessity of a proper organization of seismological investigation is a central bureau of national scope for the systematization and coordination of earthquake reports from all parts of the country, whether they have reference to earthquakes of the first class or those of only regional importance. Such a clearing house cannot be maintained by any local institution, and could only be successfully operated by an institution charging itself with the care of the whole field.

Another phase of seismological research which would be greatly advanced by a proper organization, such as might be effected by the Carnegie Institution, would comprise those studies which are necessary on the occurrence of a first class earthquake anywhere within our borders. Such great shocks do occur from time to time, and the phenomena which are their concomitants must be observed promptly and carefully by competent observers. At the present time there is absolutely no provision for such work. When such a shock does occur, as in the case of the Charleston and California earthquakes, valuable time and effort that should be given to scientific enquiry are devoted to a scramble for means wherewith to do the work.

Besides all this, we need in such an organization as is contemplated a small staff of men concerned chiefly with the theoretical aspects of the subject,—the discussion of the data from the physical and mathematical point of view. There is also needed very urgently an experimental laboratory for the purpose of investigating many questions that arise in the study of earthquakes and their destructive effects.

These various phases of this work and others that might be suggested are likely to remain undone until we have effected some kind of an organization properly financed and devoted to this particular field. State aid appears to be remote. The Seismological Society is financially weak, and its chief function will be that of educating public opinion and stimulating private effort. Under these circumstances an appeal to the Carnegie Institution to take up the work of organizing and prosecuting seismological research in this country seems to be well justified. The recent large addition to its foundation encourages the hope that the Institution may be able to do this without detriment to its other large and important undertakings. The assumption of the work by the Institution would certainly meet with the approval of the scientific men of the country.

SUGGESTED ORGANIZATION FOR SEISMOLOGIC WORK ON THE PACIFIC COAST

Suggestions made at the meeting of the Seismological Society of America held at San Francisco, January 9, 1909.

BY J. C. BRANNER

Under the topic "faults," Professor J. C. Branner was called upon and spoke as follows:

In speaking about faults I beg the forbearance of the chairman and of the members present if I fail to confine my remarks strictly to this particular topic. It is not possible for me to stay to the end of the meeting, and as these meetings are as yet far apart and at uncertain intervals, I want to use this opportunity to offer a few suggestions looking to the best interests of the science in which we are all deeply interested.

Every geologist admits the seismologic importance of faults. This importance has been so clearly demonstrated that, so far as I am aware, no one questions it. There may be earthquakes that are not due to faulting, but we are all familiar with the amount and nature of the evidence showing that the great California earthquake of 1906 was due to movement along a fault line. But it is important to note that geologists know of a great many faults which are not now centres of seismic disturbances. Such faults probably caused earthquakes at some time in the past, but they are now recemented, as it were, and, from the point of view of the seismologist, are inactive and unimportant. In the portion of the coast ranges with which I am most familiar there are literally thousands of faults, if we count both big and little. On the other hand there are probably faults so obscured by soil or by recent deposits, especially along valley floors, that we are unable to say just where they are; and there are still others that are but ill defined at the surface, or the geology of the region in which they occur may not have been studied. Indeed, one of the great difficulties that we have to face in studying earthquakes on this coast is the lack of detailed and trustworthy geologic maps.

Evidently then, and looking at the matter from the point of view of the seismologist, there are faults about which we need not concern ourselves, and there are others about which we should be very much concerned. How are we to distinguish between these two kinds of faults — the seismologically active and seismologically inactive ones?

The displacement along the San Andreas-Stevens Creek fault at the time of the earthquake of 1906 was so readily traced from point to point, and the topographic emphasis of the entire fault line was so pronounced that it is highly probable that that particular fault would have been promptly located, even if we had not previously known anything of the geology. But the cases are not always as simple as this one; and even if they were, we cannot afford to wait for such serious disturbances to wake us up to a realizing sense of our duties.

In connection with this subject of faults or epicentra, I believe that the most important work this society can undertake is to organize at once and to put into active operation a permanent and comprehensive system for collecting seismologic data. Only by such means can we hope to ascertain the locations of seismologically active faults as distinguished from the inactive ones. It naturally occurs to one that this could be done by the use of a large number of seismographs judiciously located and carefully looked after. But however important and helpful seismographs and properly equipped seismographic stations may be, their great expense puts them practically out of the question for a young organization with limited means. There is one excellent kind of a seismograph, however, that we can all use to great advantage if we will only set about it, and will take the trouble to put the records on paper and send them in. I refer to our own bodies. Earthquake scales are all based upon personal observations and impressions, and this facilitates the prompt classification of earthquake intensities. And in this matter of location of epicentra the determination of the distribution of intensities is exactly what is needed—for the present at least. In order to make work of this kind effective there should be a large number of observers widely distributed over the area studied, and their results should be made immediately available.

If you will look at the map of California showing the distribution of the stations of the U. S. Weather Bureau, a method of collecting and handling such data immediately suggests itself. Here is an organized body of men accustomed to make certain observations in a systematic manner, and to report them every day to the central office. There are 290 of these weather bureau stations in California alone. Clearly this number of observers is not nearly large enough to gather earthquake data necessary for the determination of the centers of disturbance over such a large area. The organization, however, is there, it has a head office in San Francisco, and the man in charge is one of our members, the author of the catalogue of earthquakes of the Pacific Coast for the years 1897 to 1906, and is thoroughly accustomed to assembling and using such data.

These reflections lead me to make the following suggestions regarding a method for getting active observations organized without further delay:

I. That, in order to gather data, the society make special efforts to greatly increase its membership in this state and along this coast, and that members be sought with some reference to geographic distribution.

II. That the society request all of its members to note the time and intensity of all earthquake shocks felt by them, and to send these notes to the compiler with the least possible delay.

III. That the society have the Rossi-Forel scale printed and sent to the members so that each one can have it at hand in order to determine intensities and to accustom him to its use.

IV. That Professor McAdie be made, ex-officio, the society's official compiler of earthquake data for the Pacific Coast of North America.

V. That the society become financially responsible for such clerical help as the compiler may require in connection with this work.

Such an organization as is here suggested ought to place in the hands of the compiler data for the construction of an intensity map of any considerable earthquake within forty-eight hours after the shock. I believe the gathering of such data and the construction of such maps will soon enable us to locate the active faults or centres of seismic disturbances. We shall thus be in position to serve the public by indicating the lines or localities where serious disturbances are most likely to occur and those where they are least to be expected. And all this can be done by cooperation, with the expenditure of very little money, and with the least possible amount of exertion. Expensive seismographs and skilled mechanicians are not required, and the writing of the brief reports here suggested need not take five minutes of a member's time.

I doubt if the plan here suggested would be practicable in a region where earthquakes are rare, and it may not work satisfactorily even on this coast. That we can determine only by trying it. But let us begin somehow and try out any method or all methods that appear to promise results.

In what I am here suggesting I make no attempt to cover the grounds of the possible activities of this society. There is much to be done in the way of field observations, of laboratory investigations, and of philosophic deductions. With observations made and work done I am sure the interest of the members of the society will grow, and we shall soon spread our energies into other parts of the field.

SEISMOLOGICAL OBSERVATIONS OF THE FUTURE

By Alexander McAdie

We constantly hear expressions of amazement in connection with wireless telegraphy. The transmission of intelligence over great distances and especially over the sea, without the aid of wires or cables, appeals strongly to the imagination; and few achievements of modern science have aroused so much interest and enthusiasm. The ability to receive information from distant and inaccessible points is indeed significant. But think for a moment, is not this precisely the function of a seismograph? Originally devised and intended as a means of recording the time of a local disturbance, the instrument has been so improved and its use so extended that it now serves, exactly as the receiver of a wireless outfit, to tell of conditions at a distance. Instead of an electro-magnetic wave in the unknown ether, we employ as a medium of transmission the earth itself; and for messengers, the various waves originated by the disturbance.

It is evident that as the seismograph is developed further and the laws of transmissibility of earth waves are determined, we shall acquire extensive and detailed knowledge of what is going on in the earth's crust near the surface, at all centers of activity. In other words, the seismological observatory of the future promises to become a repository of data concerning the earth as a whole. Such data will be of direct value to man in his daily life. Heretofore we have been unaware of disturbances in uninhabited and inaccessible portions of the earth; but now no displacement or equalization of strain at any point on the earth will occur without a full and enlightening record of the same being transmitted to central observatories. The value of such data cannot be fully appreciated at the present time; for as in meteorology, the assembling of simultaneous records on the synoptic chart led to great advances in our knowledge of the movements of the lower air, so the assembled records of earth movements will throw light on problems of geo-physics, ultimately unfolding the history of the planet's origin and development. The well equipped seismological observatory of the future promises to do for geognosy what the solar physics observatory is doing for astronomy in solving problems bearing on the evolution of the universe. Without doubt such an observatory will yield signficant contributions concerning the evolution of our own planet.

One can hardly imagine a more fascinating line of scientific work than interpreting seismograms, deciphering these records of earth change at far distant points. And as through the spectroscope, astronomy has in recent years been developed chiefly along astro-physical lines, so geology through the seismograph and its auxiliary will make marvellous development along geo-physical lines.

Indeed it is not looking far ahead to conceive of central observatories with a tri-sided organization whereby modern developments in geology, astronomy and meterology can be correlated. These three fields are becomming more and more closely allied and there are certain problems pressing for solution to-day, especially in connection with planetary atmospheres, which require work in all three fields. In two of the fields, astro-physics and aero-physics, great advances have been made within the last five years, and we have the promise of a glorious future in these directions. One can have little hesitation in saying that a modern geophysical observatory at some point on the Pacific Coast would mean a wonderful development of knowledge that in a certain sense would be of more direct value for the welfare of mankind than even knowledge of the stars or of the air.

REMARKABLE EARTHQUAKES IN CENTRAL NEW MEXICO IN 1906 AND 1907

By Harry Fielding Reid

Between July 2, 1906 until well into the year 1907 scarcely a day passed that slight shocks or tremors were not felt at Socorro, in the middle of New Mexico, and in its vicinity; and shocks severe enough to do some damage occurred on July 12th and 16th and on November 15th. The series was inaugurated by smart shocks at 3:15 and 3:30 a.m. on July 2d, felt probably everywhere within fifty miles of Socorro. At Socorro they were strong enough to upset small objects (VI)*, and at Magdalena, twenty miles west, somewhat less strong(V). Six shocks were reported in Magdalena between 3 and 4 a.m. and ten shocks in Socorro between 3:15 a.m. and noon; tremors continued during the afternoon and night. On July 7th smart shocks were felt at Socorro at 1:30 and 4:10 a.m. and at Magdalena about 3 a.m. (All times are in Mountain Standard Time, seven hours slow of Greenwich mean time.)

On July 12th came the first severe shock at 5:15 a.m. which lasted from fifteen to twenty seconds at Socorro (VIII). The walls of many adobe houses were cracked and some brick chimneys were thrown down. Many boulders were shaken down upon the branch railroad to Magdalena a few miles west of Socorro, breaking one rail and a number of ties. The following places report having felt the shock: Socorro, and small towns nearby (VIII); San Antonio (VII-VIII), Elmendorf, sixteen miles south of Socorro, and Carthage, sixteen miles southeast, (VI-VII), San Marcial (VI), Rosedale (IV?), Alamagordo, Silver City, Lake Valley (III-IV), Albuquerque, El Paso (III). It was also felt on the ranches to the east and southeast of Socorro. A slight shock was reported from Fort Wingate about 5 a.m. on July 11th; it is probable that this is an error and that the shock was felt on the 12th; Socorro reports only very slight shocks on the 11th and no other place reports any. The following towns report not having felt the shock: San Mateo, Estancia, Las Lunas, Peralta, Cerrillos, Las Vegas, Santa Rosa, Deming, and Roswell; the first three were probably near the limit of the sensible shock. Many light shocks were felt during the rest of the day in the general neighborhood of Socorro.

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*The Roman numerals indicate the intensities according to the Rossi-Forel scale, see page 32.

The second severe earthquake came on July 16th. Slight shocks were felt in Socorro on the previous night and a sharp one at 6 a.m. (VI?), another slight one at 10 a.m., and three strong shocks at 12 noon, 12:05 and 12:08 p.m. Lighter shocks were felt at 12:30, 1, 1:30, 2:40, 3, 4:10, 6, 8:45, 10, and 11:20 p.m., also on the 17th at 1, 3, 4:20 and 6 a.m., and more on the succeeding days.

The midday shocks of July 16th were slightly stronger than the shock of the 12th. They upset more chimneys, cracked more houses, and threw out some brick gables in Socorro, made a few cracks and overthrew a few chimneys in San Antonio and increased the apprehensions of the inhabitants. Many of the people of Socorro left their houses and lived in tents, not in general because the houses were so badly damaged, but from fear of more severe shocks which might bring the houses down upon them. The Socorro Hotel, a brick building in the eastern part of the town was abandoned on account of the injuries it had sustained, and the majority of the houses of the town suffered some damage. The southeast corner of the brick post-office was thrown out, and its eastern wall bulged; the court house and the high school lost several chimneys; but the School of Mines building, about one mile from Socorro, was not injured. A crack appeared in the adobe walk near the station, but this was insignificant, and apparently not due to the earthquakes but to drying during the hot weather. The hot springs near Socorro did not have their temperature increased as reported. Sensational accounts were published in the papers a few days later stating that Socorro was in ruins, that the inhabitants were fleeing and that a drenching rain had increased the misery. These accounts were so exaggerated as to be practically untrue; a few persons left Socorro, and the rain was unimportant.

The shocks of the 16th were felt practically over the same region as the shock of the 12th and were reported as follows: Socorro and neighborhood (VIII), San Antonio (VII-VIII), Sabinal (V-VI), Rosedale (V),Hillsboro (IV-V),Peralta (IV),Datil (IV?), Albuquerque, Rincon, El Paso (III-IV), Alto, Lake Valley, Fort Bayard (III). The shock was reported as felt at Raton, 235 miles from Socorro to the northeast, and at Douglas, Arizona, 250 miles to the southwest, but it is doubtful if these reports are correct. A train on the Magdalena branch of the railroad about ten miles west of Socorro had stopped to remove some boulders from the track, when the strong shock occurred; it nearly derailed the train and was apparently more severe at this point than at Socorro.

Light shocks and tremors continued to be felt almost daily in the vicinity of Socorro, San Antonio and Magdalena with somewhat sharper ones on July 25th at 11:50 a.m., and 30th at 3 p.m., August 5th at 11:20 p.m., and 21st, at 3:30 a.m., October 12th at 1:45 p.m., and 23d, at 11:30 p.m., November 4th at 8 p.m. and December 19th at 5 a.m.

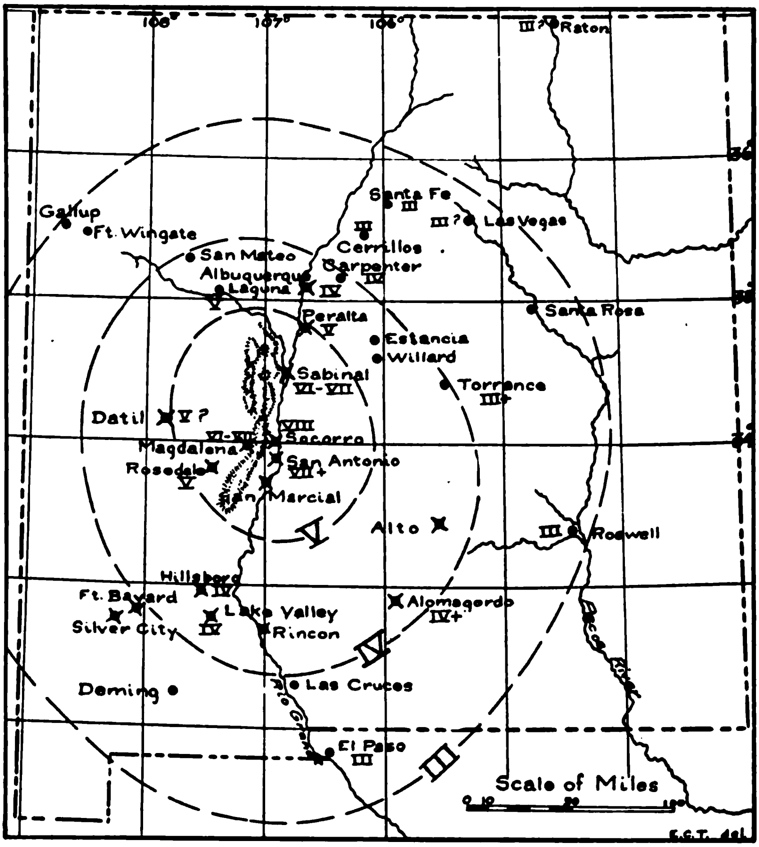
The severest shock of the year occurred on November 15th at 5:15 a.m. and was felt generally throughout central New Mexico. It increased the damage already done in Socorro, but was not much more severe than those of July 12th and 16th. Peralta reported a lighter shock at 2:10 a.m. and about thirty light shocks were felt in Socorro in the course of the day.

The intensity at various places was as follows: Socorro (VIII), San Antonio (VII+), Magdalena, Sabinal (VI-VII), Rosedale, Peralta, Laguna (V), Datil (V?), Hillsboro, Lake Valley, Alamagordo, Willard, Carpenter (IV), Albuquerque (III-IV), Estancia, Torrance (III+), Santa Fé, Cerrilos, Rosewell, El Paso (III), Las Vegas (III?). These have been entered on the map, Fig. 1, and the isoseismal lines drawn. The data are far too meagre to yield more than rough approximations to the positions of the lines. If a circle of 180 miles radius be drawn with Socorro as its center, it will include all places that felt the shock; it encloses an area of about one hundred thousand square miles, and it seems not improbable that the shock could have been felt over all this region.

It has been impossible to draw the isoseismals higher than V on account of insufficient information, for the region is not thickly settled. The isoseismal III of the shocks of July 12th and 16th probably did not differ much in position from isoseismal IV of November 15th and enclosed an area of about 40,000 square miles.

The smaller shocks usually gave the impression of a single vibration forward and back again; the stronger ones consisted of several vibrations, and the very strong ones apparently had vibrations in different directions, as is usual with strong earthquakes. Sounds, sometimes sharp, sometimes dull, and sometimes like a distant rumbling, occurred at the time of many of the shocks, though some shocks seem not to have been accompanied by sound.

In seeking the origin of this series of shocks we naturally examine the geology of the region. The Rio Grande flows in a broad flat valley on old river deposits hundreds, and in places perhaps more than a thousand, feet thick. The valley is limited a few miles from the river on both sides, by a series of mountain ranges. The whole region is cut by many faults. Flows of eruptive rock have taken place since the Tertiary Period; the Socorro Mountains, immediately west of Socorro, are eruptive; and very recent flows have occurred near Socorro, near San Marcial and elsewhere. The Magdalena Mountains consist of stratified rock resting on early igneous or metamorphic



Map of New Mexico showing the isoseismals of the earthquake of November 15, 1906. Intensities (R.-F. scale) are indicated by Roman numerals. The towns marked with a cross reported the shock of July 2 or July 16.

rock, through which more recent eruptives have forced their way; faults are very numerous.

The formation of a new fault or the movement on an old one, and volcanic explosions, are the two recognized causes of strong earthquakes. The lack of any definite evidence of volcanic activity, the sudden beginning and long continuance of the shocks, their general character and the considerable distance to which the stronger ones were felt, incline us to refer their origins to breaks or slips of the rocks; and the distribution of the intensity suggests that the slips occurred near Socorro—to the west, northwest or southwest. This suggestion is supported by some further evidence. The overthrown chimneys and gables at Socorro fell to the east and the southeastern corner of the postoffice fell outward. The chimneys and gables had their greatest lengths north and south, which would oppose their falling along that line; the fact that they fell to the east and not to the west indicates an origin in general to the west and not to the east as might be supposed; for in any sudden shock the return movement is apt to be stronger than the first forward movement; and in this case the return movement of the earth would have caused the chimneys to fall away from the origin, which would therefore be to the west. We have an example of this principle when window glass is broken by a very loud noise, such as the firing of cannon. The glass falls outward; the first forward movement of the air wave presses the glass in, and the stronger return movement draws it out and breaks it.

About the middle of July Mr. C. B. Allaire at San Antonio and Mr. J. J. Leeson at Socorro, hung up heavy pendulums to record the movement of future shocks. Mr. Allaire's pendulum marked with a pencil on paper, and Mr. Leeson's with a point in a saucer of flour. Before the end of the month Mr. Allaire had recorded two shocks strong enough to yield some information regarding their character. The first indicated a sudden movement of the earth to the southeast; during the return movement there was added a much smaller vibration in a northeast and southwest direction. The second record was like the first but the movement was east instead of southeast. Mr. Leeson reports that his pendulum indicated movements from the northwest. Dr. Bagg set up a similar pendulum in the School of Mines in 1904 and recorded a shock on the night of March 8th of that year in which the first earth movement was toward the east (see below). Unfortunately this pendulum was not kept in operation. From the little information obtainable of the region southeast of Socorro, the intensity of the shock there seems to have been less than near Socorro or a little west of it.

About three and a half miles southwest of Socorro is a lava-capped hill; a comparatively recent fault has cut through the lava and lowered the eastern portion about one hundred feet relatively to the western. A little further east, near where the Magdalena railroad crosses the arroyo, there are two faults in a sandy mud flow. It is, therefore, clear that earth movements have occurred in this region in very recent geologic time, and are probably still continuing.

These various observations lead to the conclusion that the origin of the shocks was a short distance west, northwest or southwest of Socorro. It is not probable that all the shocks occurred at exactly the same point or necessarily on the same fault, but only within the same limited region. Mr. C. T. Brown, a well known mining engineer of Socorro, examined the mines in the Magdalena and in the Socorro mountains and states that no movement occurred on the faults there; this means either that the movement was more deep-seated than the mines, or that the origin was not in these mountains.

The shocks were not very severe, and on rock foundation would scarcely have reached an intensity of more than VII; the water-soaked alluvium near the Rio Grande intensified the damage, and the lack of foundation to the houses and the poor character of the construction (the majority of the houses were built of adobe without any cementing material) permitted greater damage than would otherwise have occurred; and an intensity and destructive power was ascribed to the shocks which they did not actually have.

It is very unfortunate that there were no seismographs in New Mexico, which might have yielded more definite information about the character of the shocks; the very simple devices used for a short time at Socorro and San Antonio have helped materially in pointing out the place of origin.

Mr. J. J. Leeson, voluntary weather observer at Socorro, has sent me a very complete list of the shocks felt in his town from July 2, 1906 to January 16, 1907, which, as already stated, occurred almost daily. Unfortunately his records after the latter date were destroyed by fire, so that we do not know exactly when the frequent tremors ceased.

Light shocks have been reported at Socorro on June 6th, 16th, 17th, 28th and 29th and on July 7th, 11th and 21st, 1907. That of June 28th was also felt at Magdalena. Several shocks occurred in 1908 and five fairly sharp ones in 1909, but none during the first five months of 1910.

It seems characteristic of this region that earthquakes occur in groups. Dr. Rufus Bagg * has given some account of a series of thirty-four shocks which occurred between January 19th and March 8, 1904, and referred them to local 'displacements in the Socorro Mountains and its outliers." A long series of shocks is reported to have occurred between 1898 and 1900, but I have been unable to get definite information about it. Strong shocks were reported by Dr. Bagg on April 29, 1868, in April 1869, on July 6, 1886, and in 1897; that of 1869 seems to have been the strongest shock recorded before 1906; none of them seem to have done any material damage.

American Geologist,* **34, 102, 1904.

LIST OF SEISMOGRAPHS IN AMERICA.

[NOTE.—Anyone who knows of a seismograph in operation or about to be installed anywhere in America, and not mentioned in this list, is requested to report it to the Secretary of the Seismological Society of America, Stanford University, California.]

NORTH AMERICA

CANADA

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
McGill University	Montreal	(Not working)	Ewing duplex
Dominion Observatory	Ottawa	Dr. Otto J. Klotz	Bosch
St. Boniface Col. (S. J.)	Winnipeg	O. Rousseau	Wiechert 80 k.
University of Toronto	Toronto	Dr. R. F. Stupart	Grey-Milne
Meteorological Office	Victoria, B.C.	E. B. Reed	Grey-Milne
Grand Trunk	Prince Rupert, B. C.	(Not yet installed)	Milne

MEXICO

Servicio Seismologico Nacional, Dr. José G. Augilera, Director	Tacubaya, D. F.	F. Patiño y Ordaz	Wiechert hor. 1700 k
		H. Camacho	Wiechert vert. 1300 k.
		M. Muñoz Lumbier	Wiechert hor. 1000 k.
		A. Pastor y Giraud	Wiechert hor. 200 and 125 k.
		R. M. Tello	Wiechert vert. 80 k. Bosch-Omori phot. Schmidt Gravimeter
Ser. Seis., Station of first order	Merida, Yuc.		Wiechert vert. 1300 k. Wiechert hor. 1000 k.
Ser. Seis., Station of second order	Mazatlan, Sin.	T. Casas	Wiechert hor. 200 k. Wiechert vert. 80 k.
Ser. Seis., Station of second order	Oaxaca, Oax.	J.M.Ortega	Wiechert hor. 200 k. Wiechert vert. 80 k.
Observatorio Meteorologico Central	Mexico, D. F.	Ing. M. E. Pastrana	Poëy pend.
Collegio del Estado	Puebla	F. de P. Tenorio	Milne Contreras
Observatorio	Leon, G'to.	Prof. M. Leal	?

COSTA RICA

Servicio Meteorologico Observatorio Nacional	San Jose	P. Biolley	2 Ewing duplex
Private	San Jose	Prof. Juan Rudin	?
Instituto Physico	San Jose		Blackburn pend.

PANAMA

Ancon Observatory	Ancon	F. D. Willson	
Canal Zone	Culebra	C. M. Saville	?

UNITED STATES

ALABAMA

Spring Hill Col. (S. J.)	Mobile	Rev. Cy. Kuhlmann	Wiechert 80 k.

ALASKA

U. S. Coast and Geodetic Survey	Sitka	F. L. Adams	2 Bosch-Omori

ARIZONA

U. S. Coast and Geodetic Survey	Tucson	L. W. Weed	2 Bosch-Omori

CALIFORNIA

Lick Observatory	Mt. Hamilton	W. W. Campbell	Ewing duplex and 3-comp.
U. S. Naval Observatory	Mare Island	T. J. J. See	Bosch-Omori
Mills College	Mills College	Prof. Josiah Keep	Ewing duplex
University of California	Berkeley	Prof. A. C. Lawson	Wiechert 80 k. 2 Bosch-Omori 100 k. Omori tromometer Marvin
Santa Clara Col. (S. J.)	Santa Clara	Rev. J. S. Ricard	Wiechert and vert. 80 k.
Chabot Observatory	Oakland	C. Burckhalter	Ewing duplex
Private	Los Gatos	I. H. Snyder	Original duplex
University of the Pacific	San Jose	Prof. Louis S. Kroeck	Ewing duplex
Raja Yoga Academy	Point Loma	F. J. Dick	West

COLORADO

Sacred Heart Col. (S. J.)	Denver	Rev. Wm. Forstall	Wiechert 80 k.

CONNECTICUT

Yale University	New Haven	(Not working)	Bosch-Omori 100 k.

DISTRICT OF COLUMBIA

Georgetown University Observatory (S. J.)	Washington	Rev. F. A. Tondorf	Wiechert and vert. 80 k.
Weather Bureau	Washington	Prof. C. F. Marvin	2 Bosch-Omori

HAWAII

Magnetic Obs. Station, U.S. Coast and Geod. Survey	Honolulu	O. H. Gaarden	Milne E.-W. hor.

ILLINOIS

St. Ignatius Col. (S. J.)	Chicago	(Not yet installed)	Wiechert 80 k.

KANSAS

University of Kansas	Lawrence	H. P. Cady	
St. Mary's College (S.J.)	St. Mary's	(Not yet installed)	Wiechert 80 k.

LOUISIANA

Loyola College (S. J.)	New Orleans	Rev. A. L. Kunkel	Wiechert 80 k. and vert.

MAINE

Private	Bath	L. S. Metcalf	Omori 22 k.

MARYLAND

Johns Hopkins University	Baltimore	Prof. H. F. Reid	Milne and Bosch-Omori
Magnetic Obs. Station, U.S. Coast and Geod. Survey	Cheltenham	J. E. Burbank	2 Bosch-Omori, 100 k.

MASSACHUSETTS

Harvard University	Cambridge	Prof. J. B. Woodworth	2 Bosch-Omori, 100 k.
Massachusetts Institute of Technology	Boston	Prof. T. A. Jagger, Jr.	2 Bosch-Omori
Holy Cross Col. (S. J.)	Worcester	L. J. Haubert	Wiechert 80 k.

MICHIGAN

Detroit Observatory, University of Michigan	Ann Arbor	Prof. W. J. Hussey	2 Bosch-Omori 100 k. Wiechert hor. and vert, 100 k.

MISSOURI

St. Louis University (S.J.)	St. Louis	Rev. J. B. Goesse	Wiechert 80 k.

NEVADA

Private	Carson City	(Not operating)	Ewing duplex

NEW JERSEY

Princeton University	Princeton	Prof. W. B. Scott	?

NEW YORK

N. Y. State Museum	Albany	Dr. J. M. Clarke	2 Bosch-Omori
Canisius College (S. J.)	Buffalo	W. C. Repetti	Wiechert 80 k.
Jesuit College (S. J.)	Brooklyn	J. Glover	Wiechert 80 k.
Fordham Univ. (S. J.)	Fordham	Rev. E. P. Tirnan	Wiechert 80 k.
Cornell University	Ithaca	Prof. R. S. Tarr	Bosch-Omori 25 k.

OHIO

St. Ignatius College (S.J.)	Cleveland	Rev. F. L. Odenbach	Wiechert hor. and electric 80 k.

PENNSYLVANIA

Swarthmore College	Swarthmore	Prof. John A. Miller	Milne

UTAH

University of Utah	Salt Lake City	Prof. F. J. Pack	Bosch-Omori

VERMONT

Norwich University	Northfield	Prof. Wm. A. Shaw	(not installed)

WASHINGTON

University of Washington	University Sta., Seattle	Prof. H. Landes	Bosch-Omori 25 k.
Gonzaga College (S. J.)	Spokane	Rev. E. M. Bacigalupi	Wiechert 80 k.

WISCONSIN

Marquette Univ. (S. J.)	Milwaukee	Rev. J. L. McGeary	Wiechert 80 k.

WEST INDIES

College St. Martial	Port-au-Prince Haiti	J. Scherer	Pendulum
Magnetic Obs. Station, U.S. Coast and Geod. Survey	Porto Rico	George Hartnell	2 Bosch-Omori
Experimental Station Botanical Gardens	Trinidad	J. H. Hart	Milne
....	Kingston, Jamaica	J. F. Brennan	Milne

CUBA

College of Belen (S. J.)	Havana	Rev. G. L. Gangoili	Vicentini
	Cienfuegos	Rev. S. Sarasola	

SOUTH AMERICA

BRAZIL

Observatorio Astronomico.. Rio de Janeiro.. Dr. H. Morize.................... Bosch-Omori and Wiechert

PERU

.... Arequipa .... Milne

ARGENTINA

Observatorio Magnetico... Pilar .... W. G. Davis.................. Milne

CHILE*

Seismological Service of Chile — Count Montessus de Ballore, Director...... Santiago ..... Bosch-Omori; Wiechert hor. and vert.; and Stiattesi hor.

Second order:
- Tacna .... Wiechert hor., 200 k.
- Copiapo .... Wiechert hor., 200 k.
- Osorno .... Wiechert hor., 200 k.
- Punta Arenas............... Wiechert hor., 200 k.

The following stations of the third order are furnished with Agemennone seismoscopes:

1. Angol
2. Antofagasta
3. Calama
4. Castro
5. Cauquenas
6. Chillan
7. Concepcion
8. Constitucion
9. Evanjelista Island
10. Illapel
11. Iquique
12. Juan Fernandez Island
13. Lebu
14. Mocha Island
15. Ovalle
16. Puerto Montt
17. Punta Dungeness
18. Quillota
19. San Fernandez
20. San Filipe
21. Serena
22. Talca
23. Taltal
24. Tarapaca
25. Temuco
26. Toco
27. Valdivia
28. Vallenar
29. Valparaiso

(*The information regarding the stations in Chile is taken from the statement of the director, M. Montessus de Ballore, given in the Boletin del Servicio Sismolojico de Chile, vol. I, Santiago, 1909.)

THE NOMENCLATURE OF SEISMOLOGICAL REPORTS.

By J. B. Woodworth

At present there is much diversity among different institutions in regard to the use of symols for designating the phases of seismic waves and the data derived from their measurement. The adjoined scheme, known as the Göttingen nomenclature, has been kindly furnished the writer by Dr. Otto Klotz of the Dominion Astronomical Observatory at Ottawa, in which institution the system has been adopted for its seismological reports.

Character of the Earthquake.

I = noticeable. *II* = conspicuous. *III* = strong.
d = terræ motus domesticus = local earthquake (sensible or felt)
v = " " vicinus = near " (under 1000 km.)
r = " " remotus = distant " (1000 to 5000 km.)
u = " " ultimus = very distant " (over 5000 km.)

Phases

P = undæ primæ = first preliminary tremors.
S = " secundæ = second preliminary tremors.
L = " longæ = long waves in principal portion.
M = " maximæ = greatest motion in principal portion.
C = coda = trailers.
F = finis = end of visible disturbance.

Nature of the Motion.

i = impetus = beginning.
e = emersio = appearance.
T = period = twice time of oscillation.
A = amplitude of earth movement, reckoned from zero line.
A_E = E-W component of *A* } measured in microns (μ)
A^N = N-S " *A* }

The accompanying table presents in parallel columns a synopsis of several other schemes which are employed in various publications in this country and abroad.

I	II	III	IV	V	VI	VII	VIII	EXPLANATION
P	V_1	V_1	1	I	T	P_1	1st P. T.	First preliminary tremors.
S	V_2	V_2	2	II	C	P_2	2d P. T.	Second " "
L	B	W_1	3	III	R	—	— P. P.	Long or main waves, principal portion.
M	..	..	..	..	..	..	..	Maximum motion.
A	..	..	..	..	..	..	..	Amplitude (see note).
C	..	..	..	..	..	..	..	Tail, end portion, trailers.
F	..	..	..	..	..	..	..	End (finis).
..	..	W_2	..	..	..	..	..	First reflected long waves.
..	..	W_3	..	..	..	..	..	Second reflected long waves.
..	..	..	..	P	..	..	..	Period of a phase.

I. From the Göttingen system as given above.

II. From the reports of the Strassburg international station.

III. Given by Professor Hobbs in "Earthquakes."

IV. Numerals employed in some German publications.

V. In reports from Budapest, Hungary.

VI. In reports from Russia.

VII. Jesuit Seismological Service, Rev. F. L. Odenbach, S. J. Director, Cleveland, O.

VIII. In some English and Japanese publications.

Where in the above table no letter is given, some evident abbreviation of the term employed is usually given in reports.

By amplitude is sometimes meant the calculated amplitude of motion of an earth particle; in other reports the simple amplitude of motion as recorded by the stylus on the record is meant; some reports give both, *e. g.*, Budapest.

The Göttingen designations appear to be employed by the greater number of stations; and on the advice of Dr. Klotz they have been adopted for future publications from the Harvard station at Cambridge, Mass.

REVIEWS

TEMBLORES, TERREMOTOS, INUNDACIONES Y ERUPCIONES VOLCANICAS EN COSTA RICA 1608-1910. Datos compilados por el Lic. Cleto González Víquez. San Jose de Costa Rica, 1910. 8°, illustrated, 200 pages.

(EARTHQUAKES, FLOODS, AND VOLCANIC ERUPTIONS IN COSTA RICA, 1608-1910. Data compiled by Licentiate Cleto González Víquez, etc.)

This book is a painstaking compilation of all the available information regarding earthquakes and related phenomena in Costa Rica during a period of three hundred years. It includes data collected from ancient documents of all kinds, historical writings, newspapers, and every other available source.

The data are divided naturally into three groups:

First, the early and more or less fragmentary records of destructive earthquakes only, covering the period between 1608 and 1851.

Second, personal observations made without instruments from 1851 to 1887, inclusive.

Third, the subsequent systematic and instrumental observations beginning with the work of Mr. H. Pittier, Director of the Instituto Meterologico Nacional, and the installation of a Ewing duplex pendulum and a Blackburn pendulum in 1888.

Among the many interesting things brought out in this work we note at p. 69 that Mr. Pittier's data for 1889 show the greatest number of earthquakes occurred in the rainy months, that is in May and September. At p. 74 Mr. Pittier concludes that the foci of the Costa Rica earthquakes are in the region north of the central plateau.

Of the shocks in 1889 only seven per cent of all had an intensity as high as V, R.-F. scale. In 1890 one shock reached an intensity of VII, while ninety-seven per cent of all were below IV. The detailed records show a large number of shocks, but, with few exceptions, they are quite feeble. In 1900, for example, 103 shocks were recorded (p. 97), only one of which had an intensity of VII. In 1906 the total was 182, but none of them reached an intensity of IV. In 1909 the number fell to four slight shocks. In 1910 no shocks were recorded during the first two months, but between March 1st and October 24th there were 481 shocks recorded, one of which destroyed Cartago. A report kindly sent to the reviewer by Señor Pablo Biolley of the National Observatory, shows that during the remainder of 1910 there were recorded 25 additional shocks, all of low intensity, making the total for that year 506.

One of the most interesting papers in the volume is that by Señor Anastasio Alfaro, Director of the National Museum at San José. It deals with the effects of the earthquake of May 4, 1910,—the one that destroyed Cartago.

It is difficult to resist the temptation to quote extensively from a paper of so much dramatic and scientific interest, but lack of space forbids at present. On the subject of the possible relations of the Costa Rica earthquakes to faults, Señor Alfaro appears to think that the bulk of the evidence gathered in that country favors the volcanic rather than the tectonic theory of their origin.

A general conclusion brought out by the data of the book as a whole is that "the epoch of greatest activity of our (volcano) Irazu was in 1723 and that of Turrialba was in 1864, and in those years there were no earthquakes of even average importance. On the other hand when in 1822, 1841, 1888, and 1910, we had genuine earthquakes, these volcanoes have been inactive."

The publication of this valuable contribution to seismology was made possible by the efforts of Professor J. Fidel Tristan of San José, Costa Rica, who not only did everything in his power to get together the data, but raised the necessary funds for its printing. The book contains reproductions of many photographs showing interesting volcanic eruptions, and earthquake damages. Such a work is a great credit to any country, and shows that the people are dealing intelligently with the problems imposed upon them by nature.

J. C. BRANNER.

REPORT ON THE HARVARD SEISMOGRAPHIC STATION. By J. B. Woodworth. Reprint from the Annual Report of the Curator of the Muesum of Comparative Zoology, 1908-09, pp. 28-32.

SECOND ANNUAL REPORT OF THE HARVARD SEISMOGRAPHIC STATION. By J. B. Woodworth. Reprinted from the Annual Report of the Curator of the Museum of Comparative Zoology for 1909-10. Cambridge, Mass., 1910, pp. 27-34.

These two reports from the Harvard seismographic station consist chiefly of formal tables and accompanying notes of the shocks recorded by the two Bosch-Omori seismographs during the years 1908-09-10. The first one reproduces the E.-W. component of the record of the Acapulco shock of July 30, 1909. Among the interesting and valuable data given in the second report is a chart designed by Professor Woodworth, and based upon Laska's rules, to facilitate the work of ascertaining the epicenters of distant earthquakes. This table is available for use at any station. J. C. B.

OBSERVATIONS ON THE EARTHQUAKE IN THE UPPER MISSISSIPPI VALLEY, MAY 26, 1909. By J. A. Udden. Reprinted from *Transactions of the Illinois State Academy of Science*, III, 1910.

Professor Udden's paper is an interesting and valuable illustration of a method of study of an earthquake where the only data available are personal observations and newspaper reports, and even when the intensity nowhere exceeds VII R.-F. scale. By bringing together these observations he was able to locate isoseismals over an area eight hundred miles in diameter, lying mostly in the states of Illinois, Iowa, and Wisconsin. The area of the highest intensity (about VII R.-F.), forms a T-shaped belt extending from Bloomington, Illinois, on the south, to Kenosha, Wisconsin, on the northeast, and nearly to Platteville, Wisconsin, on the northwest. Remarks tending to discredit the value of newspaper reports of earthquakes are well met by the author's reply to the effect that such data "must be taken for what they are worth and should be used with common sense discretion." The same earthquake was described by Professor Udden in *Popular Science Monthly* for August, 1910. J. C. B.

THE SEISMOLOGIC SERVICE OF CHILE

The first number of the *Boletin del Servicio Sismolojico de Chile* was published at Santiago de Chile in 1909 under the supervision of Count Montessus de Ballore, the distinguished seismologist, and at present the Director of the Seismological Service of Chile. The first number makes a brochure of two hundred pages, and, to the seismologist, it is full from cover to cover of interesting and instructive matter.

The first article is an object lesson of so much value to the geologists of North America, especially to those of us who live in the part of the country where earthquakes are frequent, that we give a translation of most of the first three pages.

We also reproduce on a small scale, as a frontispiece, an outline map of Chile, to show the distribution of the stations established by the Seismological Service in that country.

We cannot refrain from expressing our personal conviction of the wisdom of Chile's action in establishing a seismologic service, in the choice of a director of the highest reputation as a seismologist, and of the admirable way in which the director has gone about his duties.

J. C. B.

Extract from an article in the *Boletin del Servicio Sismolojico de Chile I.*, by M. Montessus de Ballore, Director of the Seismologic Service of Chile.

The Valparaiso earthquake of August 16, 1906, shook up public opinion in Chile and showed the people at large, as well as the representatives of the government, the absolute necessity of developing in this country the study of seismic phenomena, which are probably its most characteristic natural feature. The importance of popular instruction in regard to methods of construction to withstand earthquakes was also vividly realized, and that is a part of seismology which has been completely ignored up to this time, and from which came a large part of the damage caused by that terrible event. In a word, it was realized that Chile could not do without a seismologic service similar to those established in most earthquake countries.

Don Valentin Letelier, Rector of the University, realizing the duty that rested upon him as head of higher education, proposed to the Council of Public Instruction in its session of November 9, 1906, the establishing of a seismologic service and the appointment of a European seismologist, who, besides making the requisite scientific observations, should be entrusted with giving instruction to students of architecture and engineering in the principles of construction in countries subject to earthquakes. This proposition having been adopted by the Council, the plan was finally enacted as a law, and the present director of the service came to Chile toward the end of September, 1907.

After certain preliminaries the seismologic service was organized by decree of June 9, 1908. . . . It will be sufficient to say that it was decided to establish one central observatory of the first order in Santiago for the observation of earthquakes, both in this country and at a distance.

Four stations of the second order established at Tacna, Copiapó, Osorno, and Punta Arenas, each provided with a hoirzontal Wiechert pendulum of 200 kilos, will serve for observing local and nearby shocks, while twenty-nine stations of the third order, each provided with an Agamennone seismoscope, will permit observations upon local shocks.

The stations of the second order are established in the preparatory schools, and those of the third order are according to circumstances, in charge of the instructors in the schools or of keepers of light-houses.

The Central Seismological Station at Santiago will supervise all observations, and its personnel includes the Director, an assistant, and a secretary who will also act as draftsman. The last two have been chosen from the older students of the School of Arts and Sciences at Santiago, so that they can attend to the apparatus with the necessary skill, and will be able to take them apart whenever they require cleaning or repairs.

An annual bulletin is published in the annals of the university. Twice a year the Director addresses to the Rector of the University a general report on the operations of the preceding half-year and on the general progress of the service.

The central observatory has been established in a tunnel in the park of the Santa Lucia mountain, and the work of installation, begun in January 1908, was finished in March 1909. . . . Meanwhile the Copiapó and Osorno stations were established between September 1908 and February 1909.

But it is not enough to register local or regional earthquakes or distant ones; as we know, observations of heavy shocks or those made without apparatus are just as important as those obtained by means of seismographs. This part of the service has been considered with the care it merits. Immediately after the earthquake and under the pressure of public opinion already alarmed by the frequency and intensity of consecutive shocks, the administrative authorities directed the telegraph operators of the state to report by wire strong earthquake shocks felt in their towns.

These employees are charged with certain meteorologic observations which they telegraph daily to the weather bureau of the Quinta Normal at Santiago, and every month they send in detailed reports. Earthquakes are added to the phenomena on which they are to report. Thus, with the active help of the weather bureau there has already been established and is in working order a service for macroseismic observations.

For many years the Hydrographic Office of the Navy has published a meteorological annual, the observations for which are made by the keepers of light-houses scattered along the coast of Chile from Arica to Punta Dunginess and include observations of earthquake shocks.

It therefore only remained to give further development to this organization, and this was begun by extending it to the station masters of the government railways, which was readily done in March 1909, with the cordial support of Sr. Huet, the Director General. The same will also be done with the principals of the primary schools. Finally, many private individuals have spontaneously offered their services in this connection. . . .

On the 15th of April, 1909, a course in seismology as applied to construction was begun in the University for the benefit of students of architecture and engineering.

The Pan-American Congress held at Santiago December 25, 1908, was utilized to establish official agreements with the delegates of neighboring republics, Argentina, Bolivia and Peru, for the purpose of forming a South-Andean Seismological Association so that in these four countries earthquakes may be observed according to a common plan.

THE SEISMOLOGICAL SOCIETY OF AMERICA

The California earthquake of April 1906 created an intense interest in the subject of seismology, and as one of the results the scientific men of the western coast, interested in the subject, organized a society; and, wishing to make it of more than local scope, gave it the name of the Seismological Society of America. The Society was incorporated under the laws of the State of California, San Francisco being designated as the principal place of business. A board of twelve directors is elected annually in April and these choose their own officers who are also officers of the Society.

Thus far the Society has been able to do but little to justify the name which it has assumed. All the men concerned in its organization have active duties in other lines, there being no such thing at present as a chair of seismology or a department of seismology in any American university. From the beginning the Directors have considered that the issuing of a publication should be one of the chief functions of the Society, but its membership has been small, its financial resources consequently meager, and the Directors could not see their way clear to assuming the financial burdens of a publication. However, at a meeting of the Board of Directors held December 15, 1910, it was unanimously decided that something in this line must be done, and it was thought that, if a decided effort were made to increase the membership, sufficient income could be obtained to support a quarterly publication. A committee on publication, consisting of J. C. Branner, A. C. Lawson and S. D. Townley, was appointed and as a result of their efforts the first number now appears.

The membership has already been increased by over one hundred, and all members of the Society are earnestly requested to help in still further increasing the membership, in order that the publications may be made of the greatest usefulness.

The dues have been placed low, ($2.00 per year, life membership $25.00), and the BULLETIN is to be sent free to all members. Inquiries concerning the Society or its publications and names proposed for membership should be sent to the Secretary, S. D. Townley, Stanford University, Cal.

REPORTS OF EARTHQUAKES

In the study of individual earthquakes, one of the most important things to be determined is the center or origin of the shock. This could be obtained from instrumental records if the country was provided with a complete system of seismographs properly distributed and coordinated. In the absence of such a system we must depend, for the present at least, upon the reports of interested persons feeling the shocks. Members of the Society are therefore urged to make records of all earthquakes felt by them and to send the records to the Secretary. It is not necessary to make an elaborate report. The two main points to be determined in any earthquake are the time of its occurrence and its intensity. The time should be recorded to the nearest minute. (More accurate records of time are of course desirable if they can be obtained.) The intensity should be estimated on the Rossi-Forel scale which will be found printed on the last page of each issue of the BULLETIN.

If the members of the Society would take the trouble to make these simple observations and send in the records it would help greatly in the study of these phenomena.

Send all communications to the Secretary, S. D. Townley, Stanford University, California.

NOTES

In our next number we hope to give lists of earthquake records of a large number of American stations for the year 1910.

The American Philosophical Society of Philadelphia has appointed a committee to memoralize congress with a view to establishing at Washington a national earthquake laboratory.

There will be a meeting of the International Association of Seismology on July 18, 1911 at Manchester, England. All interested in the meeting are invited to communicate with Professor Arthur Schuster, F. R. S., Manchester.

Professor Harry Fielding Reid of Johns Hopkins University will give eight lectures on seismology and related subjects at the University of California between March 28 and April 6, 1911. The following topics will be treated in his lectures:

General characteristics of earthquakes. Sudden application of forces necessary to cause them. Elastic forces. Slow earth-movements and the strains and stresses produced. Rock folding and faulting, geologic and seismic. Sudden earth movements and their narrow limits. Influence of the plastic and elastic qualities of rock.

Origin and propagation of earthquake waves. The hodograph. Paths of the waves. Deductions as to the earth's interior. The amount of energy in an earthquake and its distriution over the earth's surface. Geographical distribution of earthquakes. Periodicity. Prediction of earthquakes.

Practical study of earthquakes. Observations in the field. Collection of information. Time and intensity.

Isoseismals. The influence of the foundation. Determination of epicenter, depth and time of occurrence. The examination of a seismogram, and the comparison of seismograms. The theory of seismographs. Building in earthquake regions and the protection from earthquake damage.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE SEISMOLOGICAL SOCIETY OF AMERICA, DECEMBER 15, 1910.

The meeting was called to order by President Branner at 4 p.m. in Room 1404, Merchants' Exchange Building, San Francisco. Directors Branner, Lawson, Louderback and McAdie were present.

Dr. S. D. Townley was elected secretary pro tem. The minutes of the meeting of the Board held on September 16th were read and approved.

The President appointed the Scientific Committee, to consist as follows: C. Derleth, Jr., A. C. Lawson, J. N. LeConte, G. D. Louderback, F. L. Odenbach and H. F. Reid. The President is *ex officio* a member of the committee. The finance committee was appointed, to consist of A. G. McAdie, chairman, J. N. LeConte, and the Secretary. The auditing committee was also appointed, to consist of G. D. Louderback, chairman, C. Derleth, Jr., and the Secretary.

The retiring secretary reported that the Society has $274.17 in the general account and $234.50 in the savings account, $225.00 of the latter amount constituting a permanent fund of the dues paid by life members.

Following some remarks by President Branner concerning the policy of the Society, and after some discussion of its financial status, it was decided, by a motion duly seconded and carried, to collect the dues for the fiscal year 1910-11 but not to collect those for 1909-10, no notices having been sent out owing to the illness of the former secretary.

It was moved, seconded and carried that the President and the Secretary be appointed a membership committee to secure additional members.

Professor Lawson brought up the matter of securing funds for the purpose of establishing three lines of monuments across the San Andreas Rift. Upon motion of Professor McAdie, duly seconded and carried, a committee of three consisting of the President, Professor Lawson and the Secretary, was appointed to confer with the Board of Trustees of the California Academy of Sciences in regard to the possibility of obtaining from that body a contribution of $5000.00 for the purpose named.

The matter of starting a publication of the Society was discussed at some length, and it was the opinion of all present that this should be done. The President, the Secretary and Professor Lawson were appointed a committee on publication, upon a motion duly seconded and carried.

Six persons were elected to membership in the Society, as follows: Mr. Joseph D. Grant, San Francisco, Cal.; Professor William Libbey, Princeton, N. J.; Professor V. F. Marsters, Lima, Peru; Mr. H. L. Middleton, Boulder Creek, Cal.; Mr. Robert W. Sayles, Cambridge, Mass.; Mr. D. G. Scofield, San Francisco, Cal.

Mr. H. O. Wood made a few remarks concerning the seismographs recently installed at Berkeley, and Rev. Father Ricard some remarks concerning the mathematical formulae for the reduction of seismograms.

The Board adjourned at 5:20 o'clock.

S. D. TOWNLEY, Secretary pro tem.

ROSSI-FOREL SCALE OF EARTHQUAKE INTENSITIES

I. **Microseismic shock:** recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds; the shock felt by an experienced observer.

II. **Extremely feeble shock:** recorded by several seismographs of different kinds; felt by a small number of persons at rest.

III. **Very feeble shock:** felt by several persons at rest; strong enough for the direction or duration to be appreciable.

IV. **Feeble shock:** felt by persons in motion; disturbances of movable objects, doors, windows; cracking of ceiling.

V. **Shock of moderate intensity:** felt generally by every one; disturbance, furniture, beds, etc., ringing of swinging bells.

VI. **Fairly strong shock:** general awakening of those asleep, general ringing of bells; oscillation of chandeliers; stopping of clocks; visible agitation of trees and shrubs; some startled persons leave their dwellings.

VII. **Strong shock:** overthrow of movable objects; fall of plaster; ringing of church bells; general panic, without damage to buildings.

VIII. **Very strong shock:** fall of chimneys, cracks in walls of buildings.

IX. **Extremely strong shock:** partial or total destruction of some buildings.

X. **Shock of extreme intensity:** great disaster, ruins, disturbance of the strata, fissures in the ground, rock-falls from mountains.

OFFICERS OF THE SOCIETY.

John C. Branner..President
Andrew C. Lawson..............................First Vice-President
Alexander G. McAdie........................Second Vice-President
Charles Burckhalter...........................Third Vice-President
Joseph N. LeConte...Treasurer
Sidney D. Townley...Secretary

Board of Directors.—J. C. Branner, C. Burckhalter, W. W. Campbell, C. Derleth, Jr., A. C. Lawson, J. N. LeConte, G. D. Louderback, A. G. McAdie, C. F. Marvin, H. F. Reid, T. J. J. See, J. B. Woodworth.

Finance Committee.—A. G. McAdie, J. N. LeConte, S. D. Townley.

Auditing Committee.—G. D. Louderback, C. Derleth, Jr., S. D. Townley.

Publication Committee.—J. C. Branner, A. C. Lawson, S. D. Townley.

Scientific Committee.—J. C. Branner, C. Derleth, Jr., A. C. Lawson, J. N. LeConte, G. D. Louderback, F. L. [illegible], H. F. Reid.

NOTICE

Section 3 of Article XIII of the Constitution of the Society reads as follows: "The Scientific Committee or Council shall consist of seven members of the Society who shall have general supervision of all matters of scientific interest. It shall have power to designate sub-committees on publication, on establishment of seismological stations, and on such other matters as shall be directly connected with the collection and investigation of scientific data, or the dissemination of information."

Sections 1 and 2 of Article VI of the By-Laws read as follows: "The annual dues shall be two dollars, payable within two months after election to membership, and thereafter annually in advance on April 1st. . . . Any member upon the payment of twenty-five dollars shall become a life member and shall be exempt from the further payment of dues."

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Bulletin of the Seismological Society of America

PUBLICATION COMMITTEE

JOHN C. BRANNER, Stanford University, Cal.
ANDREW C. LAWSON, Berkeley, Cal.
HARRY F. REID, Baltimore, Md.
SIDNEY D. TOWNLEY, Stanford University, Cal.

JUNE 1911

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SURFACE MEASUREMENT OF EARTHQUAKE DISPLACEMENT.

By Alexander G. McAdie.

Aside from the records obtained by seismographs, whose proper function is to register the elasticity waves transmitted through the earth, records of surface displacements may be obtained by geodetic measurements. For many years Professor George Davidson, the first President of the Society, held the opinion that certain discrepancies in geodetic work, in the vicinity of Mount Tamalpais, might be explained on the assumption of a slight displacement due to earthquake or other causes. He believed that the triangulation data made before and after 1868 showed such displacement. In 1905 at his request a re-examination was made at the Coast and Geodetic Survey office and the conclusion was reached that a real displacement of Mount Tamalpais occurred in 1868. After the earthquake of April 18, 1906, a redetermination of the position of many points near San Francisco became necessary and representatives of the Coast Survey spent nearly a year in such work. Between July 12, 1906, and July 2, 1907, a new triangulation was made of California from Mount Toro in Monterey County to Ross Mountain in Sonoma: i.e., over an area approximately 270 kilometers (170 miles) long and 80 kilometers (50 miles) wide at its widest part.

In Appendix 3 of the Coast Survey Report for 1907, Hayford and Baldwin discuss in detail the results of the work done.

The writer is not aware of any previous piece of triangulation work on so large a scale carried out immediately after an earthquake—in a region where previous trustworthy data were available for comparison. As a result of the new measurements it is reasonably certain that Mount Tamalpais moved in 1868 and also that the Farallon Light House and Ross Mountain moved at the same time. The displacements are clearly beyond the range of triangulation errors. In brief, in 1868 a region of at least 700 square miles moved about 1.5 meters (4.9 feet) about in azimuth 168° (12° W. of N.).

"In the earthquake of 1906, points on opposite sides of the fault moved in opposite directions; those to the eastward of the fault in a southerly direction and those to the westward in a northerly direction. Second, the displacements of all points were approximately parallel to the fault. Third, the displacements on each side of the fault were less the greater the distance from the fault. Fourth, for points on opposite sides of the fault and the same distance from it, those on the western side were displaced on an average about twice as much as those on the eastern side."*

A similar triangulation for stations south of San Francisco confirms the general results given above, though the relative displacements on opposite sides of the fault and near to it are less than for points at a similar distance from the fault in the northern group of stations.

One rather unlooked for outcome of the triangulation was the discovery that as a combined result of the earthquakes of 1868 and 1906, the distance between Mount Tamalpais and Black Mountain is increased three meters (10 feet). The Golden Gate lies between these points. The distance is 79 kilometers (49 miles) and the lengthening therefore amounts to one part in 26,000.

After the earthquake of 1906, the State Commission through funds provided by the Carnegie Institution erected certain monuments for the purpose of detecting future slips on the fault. A detailed description of these can be found in Professor H. F. Reid's volume (No. 87 of the Publications of Carnegie Institution).

The Seismological Society has had a careful survey of these monuments made during May, 1911, after an interval of nearly five years. The same engineer who made the first survey, Mr. B. A. Baird, made the second measurement and a resumé of his results is published in this BULLETIN. The Society met the incidental expenses, while the Board of Public Works of San Francisco authorized the City Engineer, Dr. Manson, to detail Mr. Baird for the purpose.

Professor Lawson has proposed that a series of monuments should be erected across the San Andreas rift at suitable places and their positions carefully determined at certain times. He would have these extend at least twenty miles on either side of the rift and be composed of stable concrete piers spaced not more than two miles apart. In the opinion of the Committee to whom the matter was referred there should be at least three lines of monuments, one near the head of Tomales Bay, one near the south end of the Bay of San Francisco and one crossing the rift where it traverses the south side of Mojave Desert.

*Coast and Geodetic Survey Report, 1907, Appendix 3, page 82.

PRELIMINARY REPORT OF MEASUREMENTS OF THE EARTHQUAKE MONUMENTS IN MARIN AND SAN MATEO COUNTIES FOR THE SEISMOLOGICAL SOCIETY OF AMERICA

MAY, 1911

By B. A. Baird.

To the Seismological Society of America:

I have the great pleasure of submitting for your consideration the following preliminary report of the re-measurements of the Earthquake Monuments in Marin County and in San Mateo County, established and first measured in 1907 by The State Earthquake Investigation Commission. The descriptions of these monuments and the report of the first measurements will be found in the Report of the State Earthquake Investigation Commission, published by the Carnegie Institution of Washington in 1908, Vol. 1, Part 1, page 152.

The same theodolite was used in the work just completed (May, 1911) that was used in 1907, and the methods were substantially the same.

At Olema, the three sides of the triangle S. W. Mon.—N. W. Mon.—S. E. Mon. were measured with a steel tape, as in 1907. In 1907, these three measurements were taken as the best measures of the three sides of this triangle, and then the N. E. Monument was referred to the other three by means of a Least Square adjustment. In the present case, however, the closing of the triangles (the difference between the sum of the three angles and 180° in any triangle) was much better than in 1907, but the base-lines were not measured under as good conditions. For this reason, the base N. W. Mon. to S. W. Mon. was selected as giving mean results, and from this the other two bases were computed from the observed angles. A Least Square adjustment of the quadrilateral was then made, using as a basis the direct measure of the line N. W. Mon. to S. W. Mon. and the means of the measured and computed lengths of the lines N. W. to S. E. Mon. and S. W. to S. E. Mon.

At Crystal Springs Lake, the angles observed were so nearly the same as those of 1907, that it was considered unnecessary to measure a base-line. The original base-line here was measured under great difficulties, owing to the crossing of ravines and the climbing of steep embankments. A new base-line measured under the same conditions, especially if a different tape were used, might indicate discrepancies where no real change had taken place; or in other words, the precision of measurement through the angles with the instrument used was considered to be far in excess of that of the tape measures under the conditions. Besides, the water of the lake was much higher than in 1907, and about one-half of the original base-line was under water.

Note.—Distances above the lines are measurements of 1907. Those below the lines are for 1911. Both sets are the results of the Least Square Adjustments. Distances given are in feet.

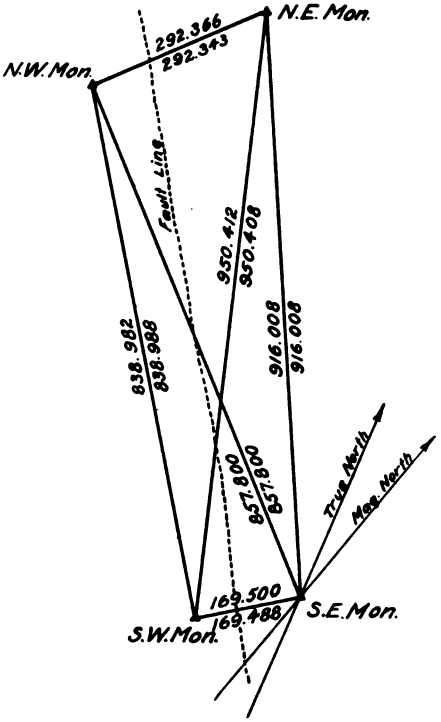


Fig. 1—Crystal Springs Lake

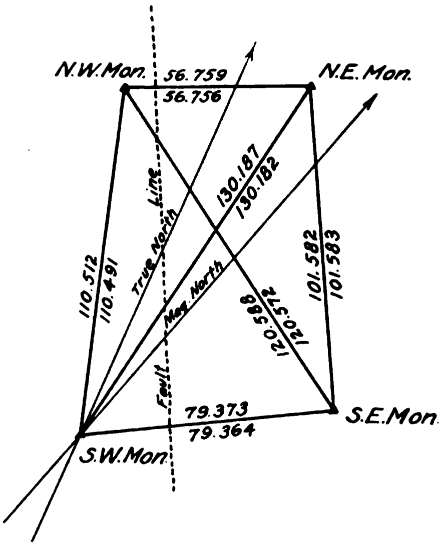


Fig. 2—Olema.

As a base for computation, the line N. E. Mon. to S. E. Mon., being on high ground, and *not crossing the Fault Line,* as well as being a long line, well suited for computation, was taken. With this base, using the distance 916.008 feet (the computed distance given in 1907 by both the ordinary field method and the Least Square adjustment), the remaining sides were computed. A Least Square adjustment of the quadrilateral was then made, using the same base.

As in 1907, however, the closing of the triangles was so close that the two methods gave practically the same results.

Comparison of Results.—At both Olema and Crystal Springs Lake, there have been, without doubt, some small changes. The figures 1 and 2 give the measurements of 1907 and those of 1911 based on the Least Square reductions, as indicated above.

At Olema, the line N. E. Mon. to S. E. Mon., being on high ground, comparatively, and being much farther from the Fault Line than the line N. W. Mon. to S. W. Mon., shows no change. The N. W. Mon. appears to have moved about 0.02 feet to the southward. This movement can be most readily accounted for, however, by the fact that, as the sketch shows, the monument is *practically on the edge of the Fault Line*—too close to be free from the local settlement so apt to take place along the broken edge of this rupture. The lengths of the two lines S. W. Mon. to N.E. Mon. and S. W. Mon. to S. E. Mon. prove that the S.W. Mon., which is much farther from the Fault Line than the N. W. Mon., has *not* moved correspondingly to the southward, and there is not the slightest evidence of any slipping or creeping along the Fault. These two distances indicate, however, that a slight closing in toward the Fault Line has *probably* taken place.

At Crystal Springs Lake, there seems to have been a closing in toward the Fault Line of about 0.02 feet at the north end, and about 0.01 feet at the south end. The longitudinal distances, however, are within a few thousandths of a foot of the original measures, and there seems to be no evidence of slipping. The closing together toward the Fault Line, of a small amount, can be explained as the direct result of the enormous pressure of the crust of the earth in bringing together once more those portions that must, of necessity, have been forced apart, to a certain extent, by the irregularities of the slipping walls, and the hardness of projecting rock surfaces.

Careful leveling showed all the monuments to have the same relative elevations as in 1907, with but one exception. The S. W. Monument has settled about 0.05 foot. This may be simply a local settlement—no theory other than this is ventured.

Astronomical observations were made for latitude and azimuth at both places. The results of this work will be taken up in the final report.

Respectfully submitted,

B. A. BAIRD,
Assistant Engineer, Bureau of Engineering,
City and County of San Francisco.

IMPRESSIONS REGARDING THE RELATIONS OF SURFACE GEOLOGY TO INTENSITY IN THE MENDOZA, VALPARAISO, KINGSTON AND SAN FRANCISCO EARTHQUAKES.

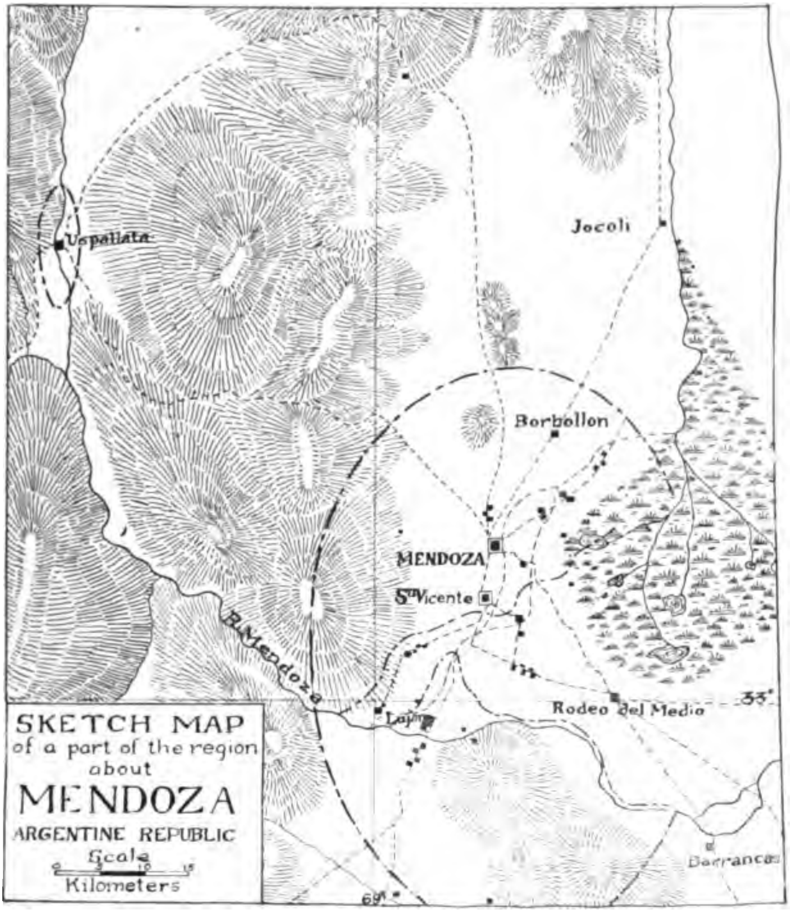
By J. C. Branner.

I had the good fortune to experience the San Francisco earthquake of April 18, 1906, and immediately thereafter to observe its effects over a large part of the surounding country. It was evident at once that within certain limits intensity was localized, and that away from the local fault it was, to a great extent, a matter of surface or near surface geology.

The study undertaken by Professor F. J. Rogers and described by him at pages 326-335 of vol. I, part 2, of the "Report of the State Earthquake Investigation Commission" seemed to point clearly to the reason for the local differences in intensity, that is incoherent materials of considerable depth and containing water enough to cause the mass to move readily. Professor Rogers' results were published in 1908, but they were known to me when I went to South America in May, 1907. His conclusions seemed so important and so far-reaching that I made a point of visiting two places in South America and one in the West Indies noted for recent violent earthquakes for the purpose of determining whether or not there was a similar localization of intensities in those cases, and if so, whether they were to be explained by the theory suggested by Professor Rogers' studies.

The places visited were Mendoza in the Argentine Republic, where there was a very destructive earthquake on March 20, 1861; Valparaiso in Chile, where there was one August 16, 1906; and Kingston, Jamaica, where they had a violent shock January 14, 1907.

Mendoza, Argentine Republic.—The Mendoza earthquake has been reported as having been so appalling that one instinctively suspects the language of being highly extravagant. Perhaps the most comprehensive description of it is that given by Dr. Don Wenceslao Diaz, in the *Anales de la Universidad de Chile* in 1907. That author says that according to the census of 1857 Mendoza had 8,678 inhabitants, and he thinks that 3,000 may have survived, a large part of whom were residents of the suburbs. This is equivalent to a mortality of sixty-five per cent, without taking into account the injured. The percentage would be somewhat increased if we assume an increase of population in the four years between the taking of the census and the earthquake.



Dr. Domeyko's estimate is that 6,000 perished; this would make the mortality sixty-nine per cent.*

The Mendoza earthquake seems therefore to have been the most destructive of modern times.

On visiting that city in 1908, and having in mind Professor Rogers' theory of the relation of water and incoherent materials to intensity, it was at once evident that the geologic conditions in the vicinity were altogether favorable to local high intensities. Mendoza stands at the eastern base of the Andes, and within sight of its snow capped summits where the perennial Rio Mendoza from the high mountains debouch upon the gently sloping plains that extend thence to Buenos Aires, a distance of a thousand kilometers. The ditches and trenches in the vicinity of the city show everywhere the materials to be heavy subangular fragments of igneous rocks, sandstones. gravels, and coarse sands washed down from the mountains, and into these beds the mountain streams rapidly sink. Just east of the city is a great marsh shown in the map on page 39, which has been prepared from the larger map accompanying the paper of Dr. Diaz. This marsh seems to have been a lake formerly, at least it is shown on some of the old maps as a lake. A considerable open stream flows through the heart of the city. Altogether it seems clear that there is much water in the ground beneath the region, and that the materials are incoherent. In the vicinity of the ruins of the former city a passing wagon causes the ground to tremble strongly.

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*Comptes Rendus, 52, 1148.

The buildings of the city at the time of the earthquake of 1861 are said to have been mostly one story adobe houses. The churches were also of adobe bricks, and the walls were very thick. My notes show that the walls of the ruins that still stand are six feet thick in places. Two of the churches stood within 300 feet of the creek.

The mountains immediately west of Mendoza are full of faults and folds and extinct volcanoes, but where the center of the disturbance was at the time of the Mendoza earthquake is not certainly known. The shock that destroyed Mendoza was sharply felt over a wide area extending to the Pacific on the west and to Buenos Aires on the east.* The map accompanying Dr. Diaz's paper shows three areas of high intensity, besides that of the city of Mendoza, but the text itself shows that the distribution of high intensity was very irregular though apparently confined chiefly to the loose materials of the plains or mountain valleys. One of these areas is on the plains about Uspallata half way between Mendoza and the pass over the Andes. But the Uspallata plain is a flat-floored mountain valley filled to a great depth with loose water-soaked materials, and it seems probable that the high intensity at Uspallata was due to these local favorable conditions.

The great loss of life at Mendoza is to be attributed to high intensity due to water in the incoherent deep gravels on which the city was built in combination with the character of the buildings.

Valparaiso, Chile.—The Valparaiso earthquake of August 16, 1906, was not nearly so impressive as that of Mendoza, so far as the loss of life was concerned. Using the data given in the book by Rozas and Cruzat, "La Catastrofe del 16 de Agosto de 1906 en La Republica de Chile," there were 3,764 deaths, which in a population estimated at 143,000 is 2.6 per cent. Yet it seems to be generally supposed that the area of highest intensity was at and about the city of Valparaiso. Maps showing the distribution of intensity are given in the paper of L. L. Zegers entitled, "El terremoto de 16 de Agusto de 1906," published in the *Anales de la Universidad de Chile,* Santiago, 1906; in the book by Rozas and Cruzat mentioned above; by Rudolph and Tams in their "Seismogramme des nordpazifischen und südamerikanischen Erdbeben am 16 August, 1906," Strassburg, 1907; and it appears also in the data given by Dr. H. Steffen in his "Contribuciones para un estudio cientifico etc.," published in the *Anales de la Universidad de Chile,* Santiago, 1907.

Herewith is reproduced a small plan of Valparaiso given originally in "La Catastrofe de 16 de Agosto de 1906 en La Republica de Chile," A. R. Rozas y C. G. Cruzat, Santiago, 1906. This map was evidently prepared without any bias in regard to geological theories of earthquake intensities. Yet it confirms in a remarkable manner the theory of the important relations of intensity to subsoil conditions.

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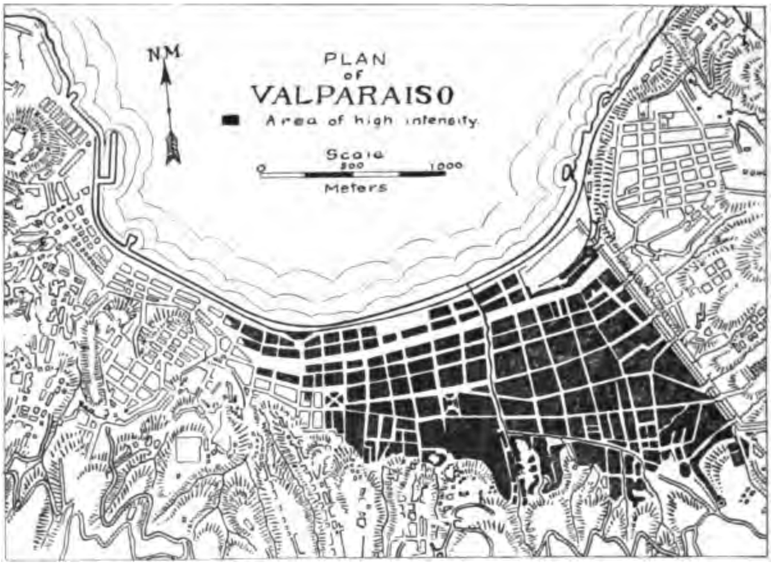
*Ignace Domeyko in Comptes Rendus, 52, 1148-1150.

The city of Valparaiso is built upon loose materials that fill the landward end of the original bay, and extends up the faces of the surrounding hills of massive eruptive rocks on all sides. The map shows that the low flat land made of loose materials and filled with water was the area of high intensity, and the contrast between the high intensity of this low ground and the low intensity of the high ground was still perfectly evident on all sides when I visited Valparaiso in February, 1908.



One point regarding local intensities not shown on this map is that the suburb Viña del Mar, a few miles north of Valparaiso, was very violently shaken. At that place, however, most of the houses stand upon flat ground of incoherent materials, but little above sea level, and into this material it is evident that much of the water from the mountains runs.

I was unable to learn of any faulting being apparent at the surface of the ground in the region about Valparaiso, and verbal descriptions show that within a wide area about Valparaiso, houses, villages, and cities located on loose water-soaked materials everywhere showed higher intensity than the neighboring areas of hard rocks.

It is worthy of note in connection with this subject that most of the cities of western South America are built upon the loose materials at the base of the mountains, and many of them are so near the ocean level that there can be little doubt about the presence of water in these materials. This is strikingly true of Callao; and Lima, though considerably higher than Callao, stands upon a plain of incoherent water filled materials.

Kingston, Jamaica.—The loss of life in Kingston, Jamaica, at the time of the earthquake of January 14, 1907, was only about 1.6 per cent. The city is built upon an alluvial fan that slopes gently seaward from the base of the high mountains a few miles north of the city. The town known as Port Royal stands upon a long slender spit that rises but little above tide level. I have not been able to obtain a map showing the distribution of intensities at the time of the earthquake of January, 1907, but inquiries made by me in that city in March, 1908, show that it is a matter of common information that the serious damage done by that earthquake was confined to the low ground, apparently of incoherent materials, and near the water. The sinking of the ground at Port Royal was, in my opinion, similar to the slumping of banks in alluvial grounds along streams of which we had so many illustrations in California at the time of the San Francisco earthquake in 1906. I find in my note-book that at the time of my visit to Kingston, I was impressed by the evidences of greater intensity of the Kingston earthquake than of those of either Valparaiso or San Francisco.

San Francisco, California.—To those who are familiar with the evidences of varying intensities in the region affected by the San Francisco earthquake of 1906 nothing is clearer than that the character of the ground was a determining factor in the distribution of intensities away from the fault where it originated. The existence of water in the ground and the influence of that water were only clear after Professor Rogers' results were known. The atlas accompanying the report of the State Earthquake Investigation Commission should be examined in this connection. The distribution of intensities in the city of San Francisco are satisfactorily explained by reference to the influence of incoherent materials containing a certain amount of water. The areas of high intensity at various distances from the fault that produced the earthquake, such as Santa Rosa, San José, Willits, Los Baños, Ferndale, and Salinas, are satisfactorily accounted for on the same theory.

THE EARTHQUAKE OF SOUTHEASTERN MAINE MARCH 21, 1904

By Harry Fielding Reid.

At 1:04 a.m., Eastern Standard Time, on March 21, 1904, an earthquake occured with its origin in southeastern Maine somewhere in the neighborhood of latitude 45° N and longitude 67° 30′ W. The shock was severe enough to cause the overthrow of some chimneys at Calais and Eastport, Maine, and at St. Stephens, New Brunswick. It was felt generally throughout the Maritime Provinces of Canada, except the eastern end of Nova Scotia, and throughout New England, the intensity diminishing in general with the distance from the center, though apparently not regularly.

Many lists of questions were sent out and newspaper reports were collected in New England, and in the Maritime Provinces of Canada. I am indebted especially to Professor J. Edmund Woodman of Halifax and Dr. F. A. Mackay, Superintendent of Education of Nova Scotia, for information regarding the shock in Nova Scotia.

The shock began gently and reached its maximum in ten or fifteen seconds and died down a few seconds later; some persons detected several maxima, and where the shock was strong the vibrations were quick and sharp; at distant points they were slower and gentler. Four or five minutes after the first shock a second one occured which was, however, distinctly weaker. At Bar Harbor, nine shocks were reported before 7 a.m., and three more during the day; on the following day one was felt at 8:45 p.m. At Bangor nine shocks were reported within two hours, and at Portland several shocks were felt. At St. Stephens, N. B., a light shock was noticed at 6 a.m. Unfortunately the information is not sufficient to enable us to decide whether these later shocks originated at the same focus as the principal shock, or were the result of local movements, induced, perhaps, by the strong shock.

Mr. Samuel W. Kain* records three light shocks felt in northern New Brunswick, on December 17, 1903, at 10 p.m., on February 27, 1904, at 11 p.m., and on February 28, at 8:37 a.m. (60th meridian time). As their origins were probably not less than 150 miles from that of the strong shock of March 21, they should be looked upon as entirely independent of it.

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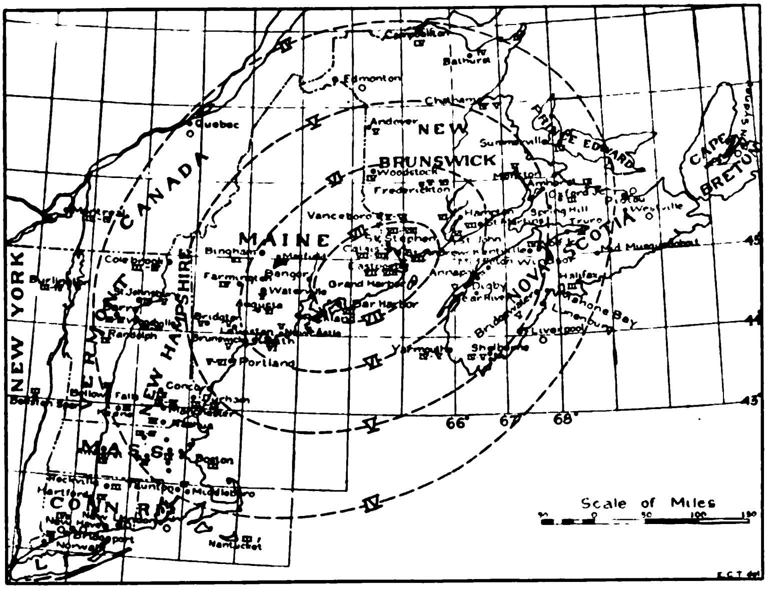
*Bulletin Natural History Society of New Brunswick, Vol. V, pp. 243-245.

When we mark on the map the intensities of the shock as reported from various places, using the Rossi-Forel scale, we see that our information is very incomplete, being entirely wanting towards the south in the region occupied by the ocean, and being almost as defective towards the northwest. Persons suddenly awakened from sleep would form a poor estimate of the intensity of the shock; and the emotional nature is so different in different persons, that they would ascribe to the same disturbance very different degrees of intensity.



Isoseismals of the Earthquake of March 21, 1904. Intensities (R-F Scale) are Indicated by Roman Numerals.

It was impossible to get information from many people at the same place, consequently correspondents sometimes reported the shock as unfelt, though other persons in the same place, who were awake, might have felt it. For instance, it is almost certain that the shock was stronger at Quebec, Can., Edmonton, N. B., and Liverpool, N. S., than at Ballston Spa, N. Y., or South Norwalk, Conn., though the former group reported the shocks as not felt, whereas it was felt at the last two places. All of these facts make our information inaccurate; but using it as well as we can, we draw the isoseismals and find them to be ovals with the long axis lying about N 35° E. It would be a matter of considerable interest to determine how closely the isoseismals follow the oval form as the distance from the origin increases. If the disturbance were spread over a line of some length, the inner isoseismals would be oval, and if the ease of propagation were equal in all directions, the more distant ones would approach circles. If, however, the disturbance were propagated more easily in any particular direction, the curves would extend further in that direction whatever be the shape of the origin. The oval shapes of the inner isoseismals, and the after shocks reported from St. Stephens, Bar Harbor, Bangor and even Portland, suggest distinctly that the fracture which caused the disturbance extended for some distance.

The severest shock originated not far from Calais and St. Stephens; and the outer isoseismals seem to extend further in the southwestern direction than in any other, suggesting a better propagation in this direction. This conclusion, however, is rendered distinctly uncertain by the inaccuracy, and especially the incompleteness of the data. It might have been better to give the isoseismals a smaller extension towards the east, but the evidence is rather contradictory, and so they have been drawn symmetrically. Professor Woodman, who has written a short account of this earthquake,* suggests that the disturbance was not felt on the gold bearing rocks of Nova Scotia, but was felt on both sides of them. Yarmouth and Lunenburg, however, both lie on this general formation and though we lack information regarding other places on the formation, we have no definite information that the shock was not felt there.

At distances far enough from the center for the disturbance to sink to the degree of IV or III, the information would necessarily be incomplete, for only light sleepers would be awakened, and at the lower grade only some of those already awake would notice the shock. It was not noticed in Quebec at a distance of about 220 miles; but was reported from Montreal, about 300 miles from the origin, at Ballston Spa, N. Y., 340 miles, and South Norwalk, Conn., 380 miles from the origin. It was reported that the shock was felt at Sydney, on the eastern shore of Cape Breton Island, distant about 350 miles, but careful inquiry there failed to confirm the report.

The shock was not recorded on the seismographs in Baltimore, Washington or Cheltenham, but the declination needle at the latter

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**Proceedings and Transactions of the Nova Scotian Institute of Science,* Vol. XI, Part II, pp. 227-235.

observatory, which is about 650 miles from the origin, showed a disturbance on its records at 1:08 a.m.; if we allow a velocity of propagation of 2.2 miles per second, which would correspond to the velocity of the strong waves of the disturbance, five minutes would be required to pass over the intervening distance; this would give 1:03 a.m. for the time of occurrence, which corresponds satisfactorily with the best observations we have regarding the time, namely, 1:04 a.m., E. S. T.

The area enclosed by isoseismal IV is about 100,000 square miles; and it seems probable that isoseismal III, which limits the area over which the shock could have been felt, enclosed an area of 300,000 square miles.

THE OBSERVATION OF EARTHQUAKES

A GUIDE FOR THE GENERAL OBSERVER

By H. O. Wood

This article is designed to put before the public in systematic, readable form such information about earthquakes as will enable ordinary observers to co-operate effectively with specially trained investigators in carrying through extensive earthquake surveys and inquiries. It is hoped that it will stimulate the widespread making of records of the behavior of earthquakes, especially throughout California and the neighboring region. It may be regarded simply as a brief manual for volunteer observers.

In the last two or three decades our knowledge of earthquakes has been greatly augmented. In large measure the invention and development of sensitive seismometric instruments has contributed to this, but, quite independently, important advances have also been made in our knowledge of earth shocks in relation to dynamical and surface geology and to works of engineering and construction.

Investigators employing delicate seismometric apparatus have discovered and demonstrated that all very strong earthquakes send perceptible wave movements all over the surface of the globe, and they find strong reasons for thinking that such motion is transmitted throughout the entire mass of the earth. These seismometers primarily are designed to discover and delineate the dynamical elements of earthquake motion—that is, the character, amount, direction and duration of the movements set up within the solid rock on which they are seated. In addition, they record the time of arrival at their stations of every phase of the wave motion; and, now, after accumulated experience, study of the seismogram permits a close estimate of the distance of the source of the disturbance, and, sometimes, an approximate notion of the direction from which it approaches. Such seismological laboratories work continually at securing information of this nature. But these as yet are very few in number, and they are distributed very irregularly over the earth, ordinarily separated by wide intervals. They are not in all cases located most advantageously. There are broad regions of the earth in which there are no such stations. Some of these districts are *often* visited by shocks. Already, nevertheless, synthesis of the investigations conducted in these laboratories has told us not merely the mode of the earth motion at such isolated localities, but how the energy is carried outward from its source, how its manifestations vary in character in different kinds of rock and at different distances from the place of origin, and how the waves traversing the earth space out at a great distance into three or more sorts running with different velocities. In this way these studies contribute matter of great value to our understanding of the constitution and physical state of the interior of the earth.

Also from these instrumental studies we learn how frequently great earthquakes occur and, in an approximate way, where they most often originate. An immediate large increase in the number of seismological stations, especially if their sites and equipment were chosen to the best advantage, would undoubtedly lead almost at once to significant advances in our knowledge of earth physics and thence, in secondary ways, to information of direct practical benefit. However, the primary purpose of such establishments is the increase of scientific knowledge. The results sought directly are not those the practical public deems of greatest importance. Direct benefit may come relatively slowly out of these investigations. Moreover it costs a great deal to build, equip, and maintain these laboratories. So it must be recognized, however regretfully, that a long time must elapse before an adequate network of stations can be established. Meantime many practical problems clamor for solution; so, while urging the building and equipping of seismological stations wherever practicable, recourse is necessary to a variety of other methods of earthquake investigation. Some of these auxiliary methods yield information of more practical value than the instrumental studies, and so, in themselves, are well worth prosecution.

To digress for a little: Instrumental seismology has demonstrated that each year recently, witnesses from ten to fifty strong earthquakes, shocks of the order that send measureable waves over the whole earth. Also Mallet, Milne and others, but especially Montessus de Ballore, have shown that these originate—with rare exceptions—in regions so related geographically that, when joined together, they form two narrow zones which in a rough way traverse the surface along great circles. These zones intersect at an angle of about 67 degrees. It is stated that more than ninety per cent of all earthquakes on record have emanated from origins within these belts. Hence they include nearly all the loci of seismic instability. Sketching roughly, one of these zones extends eastward from the Atlantic along the Alps through the Mediterranean basin, and along the Caucasus and the Himalaya. Possibly Jamaica and Central America lie in its course. The other zone borders the Malaysian Archipelago, skirts the islands along the eastern coast of Asia, including the Japanese group, follows the Aleutian chain, and sweeps along the mountainous western coast of North and South America.

Many thickly settled countries lie in or along the courses of these zones. Still, of the yearly quota of strong shocks in them, by far the greater part have origins under the sea. And a considerable majority of those originating beneath the firm land occur in places remote from the centers of civilization, and often in thinly settled localities. Sooner or later, however, the inhabited portions of these zones are shaken. In the last half-dozen years the blow has chanced to fall often and with terrible force upon thickly populated communities of high civilization: Central California, the environs of Valparaiso, Jamaica, Messina and its neighboring coasts. The total loss of life and property thus occasioned has been beyond precedent. This succession of disasters made deep impression on the present generation. Their lesson is obvious. Everywhere, and most especially in communities near the recognized seismic belts,—California being undoubtedly one of these regions,—the public should give generous support to the investigation of earthquake phenomena. And individuals in large numbers should aid specially trained seismologists in all practicable ways in the collecting of information about the occurrence and behavior of shocks.

From the point of view of human welfare the problems of first importance are these: *when* and *where* will strong shocks occur in future, and *what conditions,* which are subject to human control, tend to mitigate their diastrous consequences.

In the present state of knowledge we are, in general, unable even roughly to foretell the *time of occurrence* of shocks. There is hope of progress in this direction, but no immediate solution of the problem is expected.

The places where shocks will occur, however, and what the conditions are which may modify or control their behavior, we can already determine in advance with considerable accuracy. We know broadly the seismic belts of the world and where, in them, the districts are in which earthquakes have occurred most frequently and so are most likely to occur again. We know something, however little, about the geological causes of earthquakes and of their action under diverse geological and structural conditions. In order to determine more precisely where they are most likely to originate and to cause disaster, as well as the conditions which lessen or increase their dangers, we must carry on investigations in greater detail than has yet been done regarding the relations between the places of origin and the distribution of the perceptible effects of shocks; the relation between these effects and the geological character of the ground where they occur; how the character of structures affects the degree of the disaster,—in short, the inter-relationships of all these things, place of origin, phenomena, character of ground and of structures throughout the whole area in which the shock is felt perceptibly.

In regions where earthquakes occur frequently we need to correlate their places of origin, to compare their significant surface phenomena, to determine their distribution in time and space, all with relation to the geological structure of the district,—seeking thus to bring to light the immediate geological cause of the whole series of shocks and its mode of operation, whether this cause is acting permanently or only temporarily in the human sense, and whether the shocks come periodically or in a wholly sporadic way. For example, we already know several regions in which series of earthquakes have been caused by slip-faulting along recognized zones the courses of which are well marked by characteristic features in the land surface.

To effect such correlations adequately it is necessary to bring together complete and reliable news-accounts of the behavior of many shocks, great and small, from a great number of places in which each is felt,—in other words, to conduct a detailed seismic survey of as many earthquakes as possible. In doing this, people at large can render service of very great value. Indeed, without the co-operation of large numbers of observers little can be accomplished. Seismological stations, even if established in fair abundance, will not afford any detailed or precise knowledge of the size and shape of the area in which the shock is "felt," nor of the way in which its intensity varies over this area, nor of the character of the manifold attendant phenomena,—such as damage to structures or disturbances in the soil and rock. Such data as these can only be brought together through the co-operation of a large number of individuals living in different places who will note and report the facts which come *authenticallly* to their notice, and who will call the attention of trained seismologists to all permanent effects of the shocks. Besides its practical bearing, the results of such correlations have much scientific value, no less than the purely instrumental studies.

It is important to add at this point a warning that untrained observers should take great pains to report simply the facts observed. If they think it well to give explanations of the phenomena or theories to account for them, these should be kept distinct from the description or statement of the actual phenomena. With this qualification kept in mind, the great majority of persons whose occupation or temperament renders them observant are well qualified to aid in this work. All persons who feel any interest in earthquakes are urged to assist in collecting information about their occurrence and behavior, especially all who are situated in thinly settled or isolated localities. At best only a small percentage of the whole population will undertake such observation, so, in practice, there cannot well be too many volunteers even from the same locality. For, in general, earthquakes come at long intervals and endure only a few seconds. Even the keenest observer cannot compass all that is taking place about him. So the greater the number of persons who send in reports upon a given shock the more complete its description is sure to be. For the guidance of those who are willing to join in this work certain salient features of earthquake behavior are discussed in the following pages, with suggestions in regard to observing and recording earthquake phenomena.

THE OBSERVATION OF EARTHQUAKES

An earthquake is manifested at the earth's surface as a complex wave-motion due to vibratory movements of the rock particles, actuated by the elasticity of the rock material. These movements are set up by some sudden impulse or succession of impulses in the depths or by the sudden release of accumulated strain. Usually this earth motion is perceptible to the human senses over a region of considerable area, in which it produces a diversified range of phenomena. Immediately above the origin there is a confused and relatively violent motion with a noticeable up-and-down component. Near the margin of the affected region a nearly horizontal, gentle to-and-fro or swinging motion may be predominant. The character of the movement varies in this way with the angle of emergence of the wave trains, and thus influences the variations observed in the resulting phenomena. This variation in the character of the motion and its results helps to determine the place of origin of the shock. In the region near the origin the effects are numerous and varied, at the margin few and simple.

Serviceable records of earthquake phenomena should contain definite and detailed statements regarding:—

(*a*) The locality and whereabouts of the observer.

(*b*) The time of occurrence of the shock or shocks and of the distinguishable phases of each.

(*c*) Phenomena depending upon the energy of the shock, affording measures of its *intensity*. The transitory and permanent effects produced in nature and in artificial structures.

(*d*) The times of ocurrence, the duration and the character of the sounds accompanying the shocks, or preceding or following them.

(*e*) Sensations and emotions experienced,—dizziness, nausea, dread, etc.

(*f*) All unclassified effects.

(*a*) LOCALITY AND WHEREABOUTS OF THE OBSERVER.

Give the
State,
County,
City or Town,
Part of town (In order to identify closely the exact place of the observer at the time of the shock, give the street and number or the position of the place with reference to prominent landmarks).

Indoors or outdoors.
What floor or story.
How occupied at the moment of the shock.

In part such detailed information is necessary for accurate placement of the data contributed, in part it may be necessary for the critical interpretation of the phenomena noted, especially in the case of contradictory effects or apparent discrepancies among neighboring observers.

(*b*) THE TIME OF OCCURRENCE OF EACH SHOCK,

And so the number of them,—and of all the clearly distinguishable phases of each, should be given as closely as possible, for two principal reasons:

(1) To identify the shocks and their principal phases accurately, so that these may be compared with other similar observations of the same event.

(2) To aid in the solution of problems regarding the position, shape and depth of the focus (or foci in the case of a series of shocks), and in regard to the velocity of different sorts of earthquake waves, and to the surface factors which modify these.

To serve merely for identification of the shocks it is probably quite sufficient to give the time to the nearest minute or two, unless many shocks follow one another in quick succession.

Give the

Year,
Month,
Day,
Hour (do not neglect to specify whether a.m. or p.m.),
Minute, always as accurately as possible,
Second—*never,* unless it can be given *quite accurately.* But if attempt is made to give the time of the principal phases of the shocks, then it is necessary to state the time to the nearest second as accurately as possible.

For actual scientific service, all times should be accurately determined to the nearest second by a practised time observer—one trained to count seconds—using a timepiece whose error and rate is known or determined immediately afterward. The observer should ALWAYS *state whether he gives times accurately determined in this manner, or merely closely estimated, taking pains not to claim greater accuracy than actually pertains to the observation.*

The records of stopped clocks are interesting, particularly when the error of the clock was known and when details are given regarding the kind of clock, its placement with reference to the compass points, the nature of the base it rested on, etc.

With regard to these time observations it is suggested that telegraph and telephone operators, jewelers, railroad agents and others who are similarly associated closely with accurate time keeping, can contribute information of much interest and value.

The time of duration of each shock should be given as closely as possible, always with a statement as to whether the time given is an estimate or an accurate determination.

(*c*) THE INTENSITY OF THE SHOCK.

PHENOMENA DEPENDING UPON THE ENERGY OF THE SHOCK,—AFFORDING MEASURES OF ITS INTENSITY. THE TRANSITORY AND PERMANENT EFFECTS PRODUCED IN NATURE AND IN ARTIFICIAL STRUCTURES.

Most of the perceptible effects of earthquakes are approximately proportional to the energy of the shock at the place where they are manifested, and so serve to measure its intensity there. The observation of these effects demands a large share of attention.

When a shock occurs it is felt sensibly throughout a region roughly oval or elliptical in form for which the ratio between the longer direction and the shorter depends chiefly upon the depth, shape and character of the locus of origin of the disturbance. Further, the places in which its stronger effects are noted are found within a much smaller area near the center of the affected region, and this also is usually oval or elliptical in shape; but it is frequently more elongated than the whole region, being sometimes extremely long and narrow. Often there are more than one of these minor central areas where strong motion is manifested, and this points to a multiple origin for the shock; for the lines which separate districts in which high intensity prevails from the region less strongly shaken are determined broadly by the position of the origin or origins. In an intimate way such factors as the character of the ground at the surface make these bounding lines highly irregular and complex.

In general, intensity diminishes as the distance from the source of the shock increases; so that an accurate, detailed map of the variation in intensity determines the place of origin with considerable precision, permitting correlation of this with the geological structure of the region. Also, such a survey of the variation in intensity allows correlation of this with the character of the ground at the surface, with the nature and strength of the structures affected, etc., so enlightening us further upon the conditions which tend to lessen or increase disastrous results.

The information which auxiliary observers are asked to gather will yield a practical estimate of the intensity displayed in their localities. In spite of the conclusion reached later in this paper, namely, that auxiliary observers would better not attempt to use

THE ROSSI-FOREL SCALE.

I. *Microseismic shock*: recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds; the shock felt by an experienced observer.

II. *Extremely feeble shock*: recorded by several seismographs of different kinds; felt by a small number of persons at rest.

III. *Very feeble shock*: felt by several persons at rest; strong enough for the direction or duration to be appreciable.

IV. *Feeble shock*: felt by persons in motion; disturbances of movable objects, doors, windows; cracking (?creaking) of ceilings.

V. *Shock of moderate intensity*: felt generally by everyone; disturbance of furniture, beds, etc.; ringing of some bells. (House bells are evidently meant, such as were in general use before the introduction of electric bells).

VI. *Fairly strong shock*: general awakening of those asleep; general ringing of bells (house bells); oscillation of chandeliers; stopping of (pendulum) clocks; visible agitation of trees and shrubs; some startled persons leave their dwellings.

VII. *Strong shock*: overthrow of movable objects; fall of plaster; ringing of church bells; general panic, without damage to buildings.

VIII. *Very strong shock*: fall of chimneys, cracks in the walls of buildings.

IX. *Extremely strong shock*: partial or total destruction of some buildings.

X. *Shock of extreme intensity*: ruins, disturbance of the strata, fissures in the ground, rock falls from mountains.

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Section 3 of Article XIII of the Constitution of the Society reads as follows: "The Scientific Committee or Council shall consist of seven members of the Society who shall have general supervision of all matters of scientific interest. It shall have power to designate sub-committees on publication, on establishment of seismological stations, and on such other matters as shall be directly connected with the collection and investigation of scientific data, or the dissemination of information."

Sections 1 and 2 of Article VI of the By-Laws read as follows: "The annual dues shall be two dollars, payable within two months after election to membership, and thereafter annually in advance on April 1st. . . . Any member upon the payment of twenty-five dollars shall become a life member, and shall be exempt from the further payment of dues."

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SOME PROBLEMS OF SEISMOLOGY.

PROFESSOR A. SCHUSTER.

[Address at the opening of the Manchester meeting of the International Association of Seismology.]*

Our association primarily deals with the study of the causes of earthquakes and of their effects, but the interest which the public shows in our investigations is mainly due to the sympathy roused by the human suffering which follows the trail of these seismic catastrophes. At present we feel helpless, though perhaps not altogether hopeless, in the face of the destructive convulsions of the earth. The problem of constructing buildings which can withstand shocks of earthquakes does not enter into our program, but it has been asked, and the question will be raised during the present meeting, whether there are any preliminary indications which would allow us to predict the occurrence of a dislocation of the soil and to take precautions to mitigate, to some extent, its power of destruction. Remembering how meteorologists have succeeded in preventing loss of life at sea by predicting the course of cyclones in the Indian Ocean or the Gulf of Mexico, we might be tempted to hope that similar warnings may help us to fight the dangers of an earthquake. I am afraid that the cases are not quite analogous, and even if our knowledge should allow us in the future to form predictions of equal certainty, the dangers accompanying such predictions may overbalance its benefits. The precautions which can be taken in a harbor against an approaching storm are of a comparatively simple character, and the meteorologist is therefore justified in warning us against a probable storm which does not appear; but would the seismologist be justified in creating a panic and dislocating trade by predicting an earthquake which failed to take place? We can easily forgive the meteorologist who forecasts the weather as "fine to doubtful and stormy"; but should we forgive the seismologist when he forecasts the approaching seismic condition of our town as "calm to unstable and collapsing"? Perhaps it may seem to you that I am wandering beyond the range of practical science even in alluding to this subject; nevertheless, the fear of creating panics by premature forecasts is one which has already cast its shadows in advance, and I am informed that insurance companies in this country have shown some irritation at the early publication of the indications of a destructive earthquake which has taken place in a distant part of the world.

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*Nature, July 27, 1911.

To the man in the street the question whether a thing is large or small is all-important; to the scientific man it matters not at all; and a great part of our deliberations will deal, not with catastrophes, but with microscopic movements of the soil, movements so small that the vibrations due to the traffic in a city compare with it as the waves of the ocean with the ripples on a pool. At the last meeting of the general assembly, four years ago, you appointed a committee to investigate these microseisms. I need not remind you that there are two types of short waves which are frequently observed. One of them has independently been traced in different countries, and by several observers, to the action of the wind, which seems to create waves over an extended land surface just as it does over the ocean. The second type of vibration, which occurs in periods of from five to ten seconds, is more difficult to trace. It has been suggested that the vibrations are due to the impact of waves on the shore against which the wave strikes. For the purpose of testing this hypothesis, an instrument has been set up on the coast of Northumberland (partly paid for by the funds of this association) which automatically counts the number of waves which in a given time strike the shore. The instrument, which was designed by the Cambridge Scientific Instrument Company, Ltd., will be exhibited in this meeting. It has been set up and looked after with great ability by Mr. Morris Airey, and we are already able to say that it will fulfill its object, though the observations at present are too few to allow us to draw any conclusions.

While we rightly attach much value to the systematic investigation of minute disturbances, we must not forget to keep in mind the source and origin of all dislocations of the soil. The recent advances in physical science render it imperative to review our position with regard to this fundamental question.

In our youth we were taught that the earth, once a molten and fiery globe, had gradually cooled down, leaving the inside still hot, but gradually cooling and contracting. This contraction of the nucleus was looked upon as a primary cause of geological dislocations. But how do we stand at present? In the breaking up of radio-active products we find a source of heat which—if the amount of radium and thorium in the interior of the earth is not decidedly less than that which is found near the surface—would not only balance the earth's loss of heat by radiation, but actually increase its average temperature. Though reasons may easily be found why the surface layer of the earth may be richer in radio-active products than the core, I think that we are nevertheless driven to the conclusion that the earth is now, and has been for a long time, in thermal equilibrium, and that shrinkage by cooling does not account for any of the more recent displacements. Why, then, should not the earth long ago have settled for itself all seismic questions, and have come to rest in a comfortable state of equilibrium? After the four or five million years which it has had to calm down, we might have expected that everything should be quietly arranged in uniform layers round the centre of the earth. Instead of this regular distribution of matter, we have not only mountain chains, but also the depressions and elevations which cause the distribution of land and water over the globe.

The causes of these inequalities have long interested geologists and mathematicians, but the wider discussion of the stability of the whole structure on which we live has only recently come into prominence. The subject is a most difficult and intricate one, and a most important contribution towards its elucidation has appeared within the last few weeks. In an essay to which the Adams prize of Cambridge University has been adjudged, and which, I think, will become a classical guide to all who intend to pursue the subject, Professor Love has treated the problems of geophysics with masterly ability and lucidity. I wish it had been possible to arrange—perhaps it is still possible—for Professor Love to give you an account of his investigations, and in his presence it would be impertinent in me to explain, as otherwise I might have been tempted to do, the main conclusions at which he has arrived. I must therefore content myself with directing attention to the great importance of this work, and alluding to one suggestion contained in it which more particularly touches a subject with which this meeting is concerned.

The important work of Professor Hecker, confirmed since by others, has allowed us to trace the tidal deformation of the earth, and has brought to light the curious result that the earth appears to resist a change in shape less in the north and south than in the east and west direction.

Professor Love, having failed to account satisfactorily for the effect in other ways, suggests that the want of symmetry in the rigidity is apparent only, and that the observed effects are caused by the attraction of the tide wave in the North Atlantic and its accompanying excess pressure on the sea bottom. In the investigation of the tidal deformation of the earth, our work overlaps that of the International Geodetic Association, and a communication from that body will have to be considered by us. In other directions our work closely touches that of the geologist, and there may be points of contact with other parts of geophysics, such as meteorology and terrestrial magnetism. This interdependence of different branches of science will force us before long to consider our relations to other international associations.

MEETING OF THE INTERNATIONAL ASSOCIATION OF SEISMOLOGY, HELD AT MANCHESTER, ENGLAND.

The meeting of the International Association of Seismology was held this year at Manchester, England, on July 18th to 22d. The meeting was well attended by leading scientific men from all parts of the world; noteworthy among them were Professor John Milne and Mr. R. D. Oldham, the English seismologists, and Sir George Darwin, the astronomer, Professor F. Omori of Japan, Prince Galitzin of St. Petersburg, Professor E. Wiechert of Göttingen, and Dr. H. F. Reid of John Hopkins University, Baltimore.

Considerable time was taken up in social functions, excursions, and in the transaction of routine business.

The opening address, by Professor Schuster, was upon "Some Problems of Seismology," which is quoted elsewhere in this number of the BULLETIN.

Prince Galitzen exhibited and described his new vertical motion seismograph, which uses the same kind of magnetic damping as that employed in his horizontal pendulum. This makes the instrument aperiodic and faithfully records the earth motion.

Prince Galitzin also explained his method for finding an epicenter from records at a single station. Milne and Oldham showed years ago that the distance of the epicenter could be determined from the interval between the arrival of the first and second phases of the preliminary tremors. Prince Galitzin now shows how the azimuth can be obtained from the first indication of the seismogram obtained with an aperiodic horizontal pendulum. With the vertical component the difficulty in deciding between the opposite directions is done away with. It was shown from several examples that the estimation of the position of the epicenter by this method is as satisfactory as by the comparison of records from two or more stations.

Dr. Hecker of Strassburg presented a paper on the tidal strains in the crust of the earth; and A. Orloff gave an account of his measurements of the deformation of the earth by the moon. The methods employed were directed toward finding the effects of lunar periodicity in the movements of sensitive horizontal pendulums. It was assumed that if the earth were rigid, such movements, if due to the influence of the moon, could be calculated. But the results show a deflection of the vertical that is only two-thirds of the calculated amount. It is concluded, therefore, that the earth is affected by the tidal action of the moon. The results show also that the force acting on the pendulum is greater when it acts along an east-west line than when it acts along a north-south one. That is, the earth seems to be more rigid along east-west than along north-south directions.

It was suggested by Sir George Darwin that this difference might be due to the rotation of the earth. But Professor Love found that Hecker's results cannot be explained by reference to the earth's rotation. He attributes it to the direct gravitational influence of the tidal wave in the Atlantic upon the vertical at a neighboring locality, or to the pressure of that wave upon the ocean's bed. An inquiry into this question is to be undertaken by the International Association in connection with the International Geodetic Association, by establishing a station near the ocean, possibly at Paris, and another as far inland as possible, say in Russia.

Professor Wiechert presented an important and much discussed paper on the constitution of the interior of the earth. Broadly stated, his theory is that the earth consists of three zones or layers that differ from each other in elastic properties.

This idea appears to be borne out by the peculiar arrival of earthquake waves at the same station. Some of these waves pass directly from the center of disturbance to a given station, while other waves from the same center arrive after having been reflected very much like delayed echoes in the case of sounds. The behavior of these different waves suggests difference in the media through which they pass.

Professor Omori gave an account of certain recent volcanic and seismic phenomena in Hokkaido, and the increasing activity of another volcano, Asama Yama, which is some 8000 feet high. A seismograph has been installed on the flanks of the latter mountain. The tremors there recorded vary according as they accompany or do not accompany volcanic eruptions.

Dr. Oddone exhibited and explained an apparatus for measuring the elasticity of the rocks.

Our colleague, Dr. H. F. Reid, of Johns Hopkins University, described a new method of determining earthquake intensities based upon the fact that the energy exerted is proportional to the square of the area within a given isoseismal.

The officers elected for the next three years' period, dating from April, 1912, were Prince Galitzin, president, and Mr. Lecointe, vice-president.

THE INTERNATIONAL SEISMOLOGICAL ASSOCIATION.

By F. L. Odenbach, S. J.

The idea of an International Seismological Association was conceived by Dr. G. Gerland and the late Dr. E. von Rebeur Paschwitz. They proposed the project in the sixth International Geographical Congress held in London, where it was very favorably received. However, nothing practical was done until the meeting of the seventh Congress in Berlin, when a permanent committee was appointed. This committee met in Strassburg on April 11-13, 1901, together with the delegates of the following countries: Austria, Belgium, Germany, Japan, Russia and Switzerland, besides about fifteen scientific men from Germany, Denmark, Italy, Austria and Hungary.

Six meetings were held, preliminary statutes drafted, and a resolution passed to the effect that the German government be asked to invite other nations to a general conference with the object of initiating an International Seismological Association and Congress. This meeting has been called the First International Seismological Congress.

On July 24, 1903, the Congress met for the second time at Strassburg, and here the association was permanently organized, the following twenty-four governments joining: German Empire, Prussia, Bavaria, Saxony, Wurtemburg, Baden, Alsace-Lorraine, Argentina, Austria-Hungary, Belgium, Bulgaria, Chile, Congo State, United States of America, Great Britain, Japan, Italy, Mexico, Portugal, Roumania, Russia, Sweden, Switzerland, Servia.

In this, the second meeting of the association, the following statutes were adopted.

Statutes of the International Seismological Association.

Section 1. The object of this Association is to advance our knowledge in all such seismological problems as can only be solved by the co-operation of many stations scattered all over the world.

As principal means to this end, the following are proposed:

(*a*) Observations according to uniform methods.

(*b*) Experiments in special, important questions.

(*c*) Establishment and support of seismological observatories in countries which need the assistance from this association.

(*d*). Establishment of a Central Bureau for the collection. discussion and publication of observations gathered from different parts of the world.

SECTION 2. Members of the Association are the States which are willing to join, the reception into the Association following a request to the President of the Permanent Committee.

SECTION 3. Each state joining the Association pledges itself to contribute a certain sum for the purposes of the Association. The minimum sum total contributed for the ends of the Association shall be $5000. The payment of these contributions is to be made through the diplomatic representative of the different states in Berlin.

SECTION 4. The rate of contribution is to be as follows: A state with a population under 5,000,000 shall pay $100.

A state	with a	population of	5 to 10	million,	$200
"	"	"	10 to 20	"	400
"	"	"	over 20	"	800

SECTION 5. Organs of the Association are:

(*a*) The General Convention.

(*b*) The Permanent Committee.

(*c*) The Central Bureau.

SECTION 6. The General Convention shall consist of the delegates from the associated states. It shall meet at least every four years. A Convention is called by the President of the Permanent Committee, and he may act as the President of the Convention. The summons to a Convention must contain the program.

Scientific societies, academies and institutes interested in seismological problems may be authorized by the President of the Permanent Committee to send a delegate with consulting voice to the General Convention. The President of the Convention may also invite to the Convention.

SECTION 7. In voting on matters concerning the Association and its organs, each state represented by a delegate shall have one vote.

States whose delegates are not present may transfer their vote to one of the other delegates present.

In order to legalize the resolutions passed, the presence of at least one half of the state delegates shall be required.

A decision on a subject not contained in the program is valid if supported by at least one half of the delegates of the associated states.

SECTION 8. For scientific questions, committees may be appointed; and all delegates are privileged to attend the meetings of such committees.

SECTION 9. In complex or doubtful questions the vote must be taken by states as soon as this is requested by a single state delegate.

SECTION 10. In case of a tie, whether the vote be cast by delegates or by states, the President shall have the deciding vote.

SECTION 11. The Permanent Committee consists of the Director of the Central Bureau and a delegate from each associated state.

The Permanent Committee elects from its midst a President, Vice-President and a Secretary.

The Director of the Central Bureau can not be elected President of the Permanent Committee.

The correspondence of the President of the Permanent Committee with the Associated States is carried on through the diplomatic representatives of such states in Berlin.

The Permanent Committee carries on its business either in meetings or through correspondence. It fixes its own program.

It enforces the resolutions of the General Convention and takes care of the funds allowed by the convention for special purposes.

SECTION 12. The contributions from the different states and other money acquired is to be used:

(*a*) For publications and the expenses of the association.

(*b*) For the salary of the secretary.

(*c*) For the support of special investigations decreed by the General Convention.

(*d*) For the organization and support of observatories established by the association.

The distribution of funds is made by the Permanent Committee. The Director of the Central Bureau is responsible for the payments and he is controlled in turn by the Permanent Committee.

All payments are made by the Director of the Central Bureau on a notice from the Permanent Committee.

Accounts are to be published in the proceedings of the Permanent Committee.

The surplus of one year is to be made use of for the expenses of the next.

SECTION 13. The Central Bureau is to be connected with the Imperial German Central Station for Seismology at Strassburg.

The Director of the latter to be at the same time Director of the International Association.

The personnel and means of that Central Station shall be at the disposal of the Central Bureau.

The Central Bureau collects the observations from the different countries and publishes them.

SECTION 14. The Director of the Central Bureau makes a comprehensive report each year to the President of the Permanent Committee, adding at the same time a program for the following year.

Both the program and the report are to be transmitted to the delegates of the associated states.

In scientific matters the Director communicates directly with the members of the Permanent Committee, the National Seismological Bureaus, or with scientific societies and individuals.

SECTION 15. The Secretary reports to the General Convention regarding the condition and work of the Association.

It is his duty to publish the proceedings of the General Convention, those of the Permanent Committee as well as any matter decreed by the General Convention.

He carries on all correspondence and business of the Association under the direction of the Permanent Committee.

SECTION 16. These statutes shall remain in force for the period of twelve years, beginning with April 1, 1904.

They shall be binding on all associated states for this period and then for periods of four years, unless a notice to indicate a withdrawal has been given six months in advance.

NOTE—Prof. Harry Fielding Reid is the Delegate for the United States of America. Our National Bureau is still an object much to be desired.

AN EXPERIMENTAL INVESTIGATION OF THE RESISTANCE OF MASONRY TO VIBRATION, WITH SPECIAL REFERENCE TO THE EFFECT OF EARTHQUAKE WAVES.

By R. W. Bierer and T. B. Parker.

The object of our thesis was to investigate the mechanical effects of earthquake motion, and to construct an apparatus which would enable us to study the effects of artificial shocks upon brick and concrete columns. As a result of consulting the best authorities on the subject, we decided that although the vertical component of the motion is sometimes much in evidence, the horizontal component may be given chief attention as productive of destruction.

To imitate horizontal waves, we designed an apparatus which would oscillate a shaking table for testing full-sized columns. On a platform, columns of different sections and materials were tested to determine how intense a shock they would resist. Also a test was made to determine the weakening effect, if any, on columns subjected to repeated shocks not severe enough to cause fracture. The apparatus gives harmonic motion of varying amplitude, from zero to three inches, in a horizontal plane.

Five brick columns laid in cement mortar were tested, two being 16 inches square and three 12 inches square, and 8 feet high. In each case the column was rigidly secured before testing and the test continued till fracture occurred. Two 12 inch columns were subjected to vibrations of continuously increasing amplitude and constant period. Another was tested by increasing the intensity of shocks at short intervals and studying the action of repeated vibrations. The 16 inch columns were tested in like manner, but after a powerful vibration was obtained the amplitude was not increased and the column was allowed to shake till failure occurred.

From the data obtained it was possible by Omori's formula to determine the tension stress. This was much greater for the columns tested rapidly than for prolonged tests. This clearly shows that a column may stand under one shock, and fall under repeated shocks. Also that although the tension at time of fracture in the large columns was less than in the small, that they will stand severer shocks longer.

Four unreinforced concrete columns, 8 feet high, were tested, two of these being 10 inches square, and two 12 inches square. The shocks were increased at short intervals until fracture occurred. The columns resisted shocks twice as severe and longer than the large brick columns, and developed a much higher unit stress. All the details of failure were observed and noted.

We hope that our experiments will be continued, and believe that by the methods employed much valuable information may be obtained.

A SMALL LIBRARY ON MODERN SEISMOLOGY.

By F. L. O.

Robert Mallet—The great Neapolitan earthquake of 1857. The first principles of observational seismology. 2 vols. 830 pages. London, 1862. (Note.—This book, though not modern, is of great interest to students of seismology.)

Schmidt—Studien über Vulcane und Erdbeben. Leipzig, 1881.

Edward Suess—Das Antlitz der Erde. Leipzig, 1885-1908. The French translation has the title "La face de la terre." Paris 1897-1908. The English translation by H. B. C. Sollas is entitled "The face of the earth." 4 vols. Oxford, 1904-1908.*

F. Fouqué—Les tremblements de terre. 328 pages. Paris, 1888.

Rudolph Hoernes—Erdbebenkunde. 452 pages. Leipzig, 1893.

John W. Judd—Volcanoes: what they are and what they teach. 381 pages. New York, 1895. ($2.00)

John Milne—Seismology. 452 pages. International Science Series. London, 1898.

Edward S. Holden—A catalogue of earthquakes on the Pacific Coast, 1769 to 1897. Smithsonian Miscellaneous Collections, no. 1087. 255 pages, 8vo. Washington, 1898.

John Milne—Earthquakes and other earth movements. 376 pages. New York, 1899. ($1.75)

August Sieberg—Handbuch der Erdbebenkunde. 362 pages. Braunschweig, 1904.

C. E. Dutton—Earthquakes in the light of the new seismology. 314 pages. New York and London, 1904. ($2.25)

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*Note.—The French edition of this work is the best of the three, owing to its having many notes and additions not contained in the original or in the English translation.

DAIROKU KIKUCHI—Recent seismological investigations in Japan. 120 pages. Tokyo, 1904. ($1.25)

CHAS. DAVISON—A study of recent earthquakes. 355 pages. New York and London, 1905. ($1.50)

F. DE MONTESSUS DE BALLORE—Les tremblements de terre. 475 pages. Paris, 1906. ($3.00)

WM. H. HOBBS—Earthquakes. 336 pages. New York, 1907. ($2.20)

ALEXANDER G. MCADIE—Catalogue of earthquakes on the Pacific Coast, 1897 to 1906. Smithsonian Miscellaneous Collections, XLIX, Publication no. 1721. Washington, 1907.

C. G. KNOTT—The physics of earthquake phenomena. 283 pages. Oxford, 1908. ($4.50)

F. DE MONTESSUS DE BALLORE—Le science séismologique. Les tremblements de terre. Paris, 1908.

California State Earthquake Investigation Committee, A. C. LAWSON, Chairman—The California earthquake of April 18, 1906. Two volumes and atlas. Published by the Carnegie Institution. Washington, 1908. ($17.00)

Vol. 2. The Mechanics of the Earthquake. By H. F. REID, 200 pages, 1910. ($2.00)

WM. H. HOBBS—The evolution and outlook of seismic geology. Proceedings American Philosophical Society, XLVIII, no. 192. 44 pages. Philadelphia, 1909.

SEISMOLOGICAL JOURNALS.

Transactions of the Seismological Society of Japan, I-XVI. 1880-1892. Continued as the Seismological Journal of Japan. I-IV. 1893-95.

Beiträge zur Geophysik, Dr. Geo. Gerland and Dr. Emil Rudolph, editors. Ten volumes and three supplements published to date. Leipzig, 1887- (Organ of the International Seismological Society. Very important.)

Publications of the Earthquake Investigation Committee (E. I. C.) of Japan (in foreign languages). Edited by Dr. F. Omori. Tokyo, 1897-

Mittheilungen der Erdbebenkommission der kaiserliche Akademie der Wissenschaften in Wien. Vienna, 1897-

Publications du Bureau Central de l'Association Internationale de Sismologie. Strassburg.

NOTES ON THE CALIFORNIA EARTHQUAKE OF JULY 1, 1911.

An earthquake occurred in central California July 1, 1911, which seems likely to be of much interest, especially when studied in connection with the great California earthquake of 1906.

Data are now being gathered which, it is hoped, may enable us to determine the epicenter. At present we give the following valuable notes, kindly furnished by the observers whose names are given in each case. The reports are arranged geographically, from north to south.

Ukiah, by James D. Maddrill.—So far as I have been able to learn no one in this vicinity felt the earthquake of July 1st. The only instrument at the Latitude Observatory of the International Geodetic Association that could record a light shock was the Richard barograph, which showed no disturbance on its record sheet at or near the reported time.

Rio Vista, by J. C. Stanton.—The shock corresponds almost perfectly with the R.F. scale VI. The direction as given by the oscillation of electric drops was about NW. and SE. Geographic position of Rio Vista: latitude 38° 9′ 19″, longitude 121° 41′ 49″, according to U. S. Coast and Geodetic Survey 1908.

Mare Island, by T. J. J. See.—The time of the shock of July 1st at the U. S. Naval Observatory, Mare Island, was 2h 1m 35s p.m. as recorded by the stopping of our mean time transmitting clock.

Stockton, by Edward Hughes.—The earthquake of July 1, 1911 was felt at Stockton at 2h 00m 55s p.m. This time must be very nearly correct, as I looked at my watch during the progress of the shock, and immediately afterwards corrected the time by comparison with clocks that get their correction daily from Mount Hamilton. I estimate the duration from fifteen to twenty seconds.

A number of clocks were stopped, people were alarmed and ran into the streets. No swaying of trees was noted; there was no damage to buildings of any kind, and but little notice was taken of the shock by the people generally.

Yosemite Valley, by J. E. Gardner.—The earthquake of July 1st was very slightly, but unmistakably, felt in the Yosemite Valley; it was noticed, however, only by persons who were sitting still when it occurred.

Berkeley, by A. O. Leuschner and S. Einarsson.—The earthquake began without preliminary tremor at 2h 00m 28s ± 2s. The period of vertical vibration was approximately three seconds, indicating that the center of the earthquake was not as close as one might be tempted to suspect.

The total duration of the motion as shown by the records was roughly twenty-seven minutes: of which eighteen minutes was marked by perceptibly strong motion; ten minutes as heavy motion; and five minutes by great intensity. The intensity was V on the Rossi-Forel scale; it was a smart shock, generally felt; furniture was shaken; and some clocks, notably the time clock of the Students' Observatory, were stopped—this for the first time since the earthquake of April 18, 1906.

The pens of the horizontal machines jumped the paper. These machines are, however, constructed primarily for the recording ot very distant rather than local earthquakes, so that their dislocation is not in any sense an indication of a particularly severe earthquake.

There was on the horizontal as on the vertical machines no preliminary tremor, and the computation of the distance depending on the preliminary tremor cannot therefore be given. There was no record on the north and south or on the east and west components. The amplitude of the vertical motion was about 2/100 of an inch, and the suddenness and short period of the shake gave added severity, There is no question but that it was a local earthquake, probably within a radius of fifty miles.

The *perceptible* shock came in two parts, the first lasting about five seconds; the second was less sensible and intense, and there was a lull of five seconds between.

The unusual and interesting feature of the earthquake is that there was no preliminary tremor.

Seismographic Station, Berkeley, by H. O. Wood.—There are discrepancies in the registered time of beginning of the shock of July 1st which necessitate explanations. I had gone into the mountains for the summer some two weeks previous, leaving everything in good running order. I left the instruments under the care of a substitute who took the place of our regular assistant during June while he was away on vacation. The regular man resumed his duties on the morning of July 1st. He reports to me that he found some things in bad order and that he did not have opportunity to get the station into good working condition before the coming of the shock. The condition of the records verifies his statement.

The recorded times of beginning registered by the seismographs are as follows:

N-S Comp.	2h 00m 38s plus p.m.
E-W "	(No time — time-marker caught)
Vert. "	2 00 19 minus.

I regard the time determined by the vertical instrument as good, for the machine was running well; the beginning is sharp and sudden and the pen continued to write. . . . Nevertheless the beginning on the N-S is sudden and sharply marked, with no suspicion of earlier motion, and the time measurement is good. The only thing in doubt is the parallax of the writing-point, which both before and after this shock was —21s. I am unable to explain the resulting discrepancy.

Chabot Observatory, Oakland, by Charles Burckhalter.—The earthquake of July 1, 1911 occurred at 2h 00m 28s p.m. P.S.T. I was away on my vacation, and the time was observed by my assistant, Mr. Milan E. Hunt. He reports the duration as forty seconds; general direction NE.-SW., intensity VI R.F. scale, and both sidereal and mean time clocks stopped. From what I heard after returning home the intensity may have been a little less than VI.

San Francisco, by Alexander G. McAdie.—A severe shock was felt in San Francisco on July 1, 1911, at 2:00:05 p.m. to 2:00:25 p.m., 120th meridian time, or 22 hours, Greenwich mean civil time. No tremulous motion was felt before the principal disturbance nor was there any racking motion at the end. There were two well-marked vibrations with an interval of five seconds. The vertical motion was perceptible. The apparent direction, from west to east. Few objects were overturned and the duration of sensible motion was about twenty seconds. The intensity was VII on the R.F. scale. No sounds were heard.

The shock was the most pronounced since that of April 18, 1906. Regarding general conditions in the city, there was for a few minutes general uneasiness and much excitement. In some of the crowded buildings people rushed to the doors and ran into the streets. There was however no damage of any consequence. Business went on as usual after a few minutes. Many people, especially those riding in street cars, did not feel the shock.

San Francisco, by George Davidson.—I timed the shock of July 1, 1911 at 2:00:15 Pacific standard time. Seven or eight seconds later there was a second but much lighter shock. The vibrations died out rapidly within the next five seconds. The motion was vertical. An examination of many objects on tables, etc., showed no lateral movement or twisting.

My daughter was on a Market street car going toward the ferry. She and other passengers saw hundreds of people rushing into the streets. At the next block a passenger got on the car and reported the earthquake, which no one on the car had felt. This passenger stated that he felt the shock while walking.

Modesto, by E. C. Templeton.—A meager report from Modesto states that the earthquake was clearly perceptible there, but did no damage.

Stanford University, by S. D. Townley.—When the earthquake of July 1st came I was standing on the front porch at my home, and almost immediately went inside the house. No preliminary tremors were felt and no sounds, other than the rattling of the building, were heard. There were two shocks lasting from five to ten seconds each with an interval of a few seconds between them. The two maxima were of about equal intensity,—possibly the second was the stronger. Intensity was VI on the Rossi-Forel scale. The direction from which the disturbance came could not be distinguished and no distinct vertical motion was felt. A pile of unbound *Sciences* on top of a bookcase on the second floor fell toward the southwest. A clothesbrush on top of the same bookcase fell toward the northwest. Both were more or less constrained to move in the direction in which they fell.

The University buildings were not damaged except for a few cracks in plaster. In the chemical laboratory some plaster that was already loose was thrown to the floor.

The Western Union operator at Palo Alto states that the standard clock in the office was stopped at 2h 00m 33s p.m. Pacific standard time. The clock is set every day at noon, and was probably within one second of the correct time. It is likely that the beginning of the shock was several seconds earlier than the instant when the clock stopped.

Professor Griffin, who was outside at Stanford University when the shock occurred, states that it was preceded by a distant rumbling noise advancing from the north.

Santa Clara Jesuit Seismologic Service, by J. S. Ricard, S.J., Di-

rector, and A. J. Newlin, Assistant.—This was the most severe shock since April 18, 1906. The tracer was thrown off the paper but quickly replaced. Apparently little damage done in this vicinity. Pulsatory oscillations since June 26th. Santa Clara epicenter. No preliminaries. Character III d. Time 22:00:07 mean civil Greenwich (2 p.m., 120th meridian time). Distance 81.62 kilometers east 36° 52′ S. During July shocks were recorded on the 5th, 8:33:52 mean Greenwich time. Distance 74.35 kilometers east 5° 29′ S.; and again on the 8th at 9:39:03 and at 11:47:56. Also on the 12th at 4:55, the 14th at 14:21:21; 18th at 21:55; 21st and 31st.

San Jose, by Maurice Connell.—This was one of the severest shocks since the memorable quake of 1906. It occurred at 2:00:30 p.m. The movement seemed to be entirely vertical, which would indicate that the origin of the disturbance was near San Jose. There was a loud roaring noise. The period of active disturbance did not last more than ten seconds. The damage was not great. Plaster fell and some brick walls were cracked. The post-office building was severely shaken; but with the exception of falling plaster in the upper story and some cracking of the walls, the damage was not serious. There were some after-shocks during the evening, the last noted occurring at 9:19 p.m.

Arroyo Valle, seven miles northeast of Lick Observatory, Mount Hamilton, by E. C. Templeton.—At a camp at the above location the earthquake is reported as having been strong. It caused several slides of loose rock of a number of tons each, and it perceptibly increased the flow of some of the smaller tributaries of the Arroyo Valle. It also muddied up the streams for a short time.

Mount Hamilton, by R. G. Aitkin.—The earthquake of July 1, 1911, was in some respects the most severe one experienced since the Observatory was founded. The amplitude of vibration was less than in the shock of April 18, 1906, and the duration was much less, but the motion was more violent.

Fortunately, the telescopes and other instruments of the Observatory suffered no injury with the exception of the Riefler clock. The steel springs in the pendulum support of this clock were broken, allowing the pendulum to fall and break the air tight glass case. The 36-inch telescope was moved about three-quarters of an inch to the south, the great base plate slipping on the masonry pier. The telescope was put into position again promptly and without difficulty, and has suffered no harm whatever. It stood entirely idle for one night only. The other telescopes were not affected.

The damage to the observatory buildings consists mainly of broken plaster and cracked chimneys, with the exception of the large brick residence which stands directly east of the main Observatory building. The earthquake vibration bulged the north and south walls of this building and produced shear cracks in all walls, particularly around windows. Extensive repairs will be necessary to make it safe, and it may be decided to take it down entirely. It should, however, be said that the construction of this house did not specially fit it to withstand earthquake vibration, and that the walls had been weakened by the shocks of 1903 and 1906. The walls of the other brick residences on the mountain were uninjured.

Mount Hamilton, by C. C. Kiess.—The earthquake of 1911, July 1st was one of the most severe ever experienced at Lick Observatory. The vibrations lasted from twelve to fifteen seconds, reaching maximum intensity eight or ten seconds after the beginning. So far as the writer has been able to find out, the quake was unattended by preliminary tremors or earth sounds.

The times of the beginning of the shock as recorded by the Wiechert seisomographs are:

	h	m	s		
E-W	2	00	4.6	p.m.,	P.S.T
N-S	2	00	2.5	p.m.,	P.S.T.
V	2	00	4.0	p.m.,	P.S.T.

With these times, the times of beginning noted by various individuals are in very close agreement.

The shock was of intensity VII on the Rossi-Forel scale, and was most severe in the north-south component of vibration. These facts were made evident by the effects that the earthquake had upon instruments, buildings, etc.

All of the seismographs were put out of commission almost instantly. The recording pens of both the Wiechert instruments were thrown from their carriages after making one violent sweep across the sheets. The 200 kg. mass of the horizontal was distorted and shifted northward on the pendulum, and one of the cardan springs of the vertical was sheared. The Ewing instruments withstood the shock no better than the Wiechert. The N-S pendulum was shaken bodily from its bearings, and the E-W was swung out of its normal position, causing the pen to leave the plate. Furthermore, the time clock was shaken from its support, and accordingly no time record was traced on the smoked disc. The pendulum of the Duplex was disjointed, and consequently only a partial record was traced by its pen.

The Ewing seismograph and the Wiechert vertical were put in commission as soon as possible after the violent shock. The following list of after-shocks (except the first) was recorded by the vertical, none of them being of sufficient intensity to affect the Ewing.

	h	m	s				
1911, July 1							
	*4	55	10	p.m.,	P.S.T.	Intensity	II
	6	5	16.7	"	"	"	II
	7	0	21.7	"	"	"	III
	10	19	32.9	"	"	"	I
July 2							
	12	0	25.5	a.m.,	"	"	II
	5	31	29.4	"	"	"	III
	12	36	5.5	m.	"	"	III
	3	19	42.6	p.m.,	"	"	I
	5	33	59.7	"	"	"	II
July 3							
	6	48	34.3	a.m.,	"	"	II-III

On July 3d the Wiechert horizontal seismograph was partially readjusted and the following shocks were recorded by it as well as by the vertical. The times given are the mean of the times taken from the separate records.

	h	m	s				
July 4							
	12	33	38.1	p.m.,	P.S.T.	Intensity	I
	5	43	48.5	"	"	"	I
July 5							
	**4	20	31.5	a.m.,	"	"	I
July 7							
	***11	13	19.4	"	"	"	I
	9	50	49.0	p.m.,	"	"	I
July 8							
	1	38	55.7	a.m.,	"	"	I
July 11							
	**7	39	27.2	"	"	"	II

---

*Reported by R. G. A.

**Recorded by horizontal only.

***Recorded by vertical only.

July 14						
h	m	s				
6	21	15.9	"	"	"	I
**6	54	33.7	"	"	"	I
**7	1	42.3	"	"	"	I
July 20						
3	2	11.2	p.m.,	"	"	I
4	9	30.7	"	"	"	I
5	27	42.5	"	"	"	I
July 21						
3	10	58.9	"	"	"	I
July 23						
9	54	57.5	"	"	"	I

Smith Creek, Mount Hamilton road, by E. C. Templeton.—A short report from the Smith Creek Hotel region on Mount Hamilton states that the earthquake was very severe. It caused an increase in the flow of Smith Creek at this point from nine-tenths second feet to three and six-tenths second feet. Up to September 20th the stream had not returned to its former flow. A second shock at about seven o'clock the same evening is reported.

Edenvale, by E. C. Templeton.—A water-tank two miles southeast of Edenvale station was shaken down. On Coyote Creek, one mile northeast of Edenvale, the earthquake is reported as having been very severe. At this point the stream runs in a northwesterly direction and the water was thrown out on the southwest bank by the shock. A man standing in the creek bottom was able to keep his feet only by the aid of a prop used for a clothes-line support at his camp. The earthquake cracked the loose gravels at the side of the stream, and caused a large number of small gravel slides. Two men report a second shock in this neighborhood about seven o'clock the same evening. On the firmer ground above the creek bed the houses were not damaged appreciably. At one house near here, the most serious damage was the disconnecting of a water pipe at a windmill. The intensity near Edenvale probably reached VII R.-F.

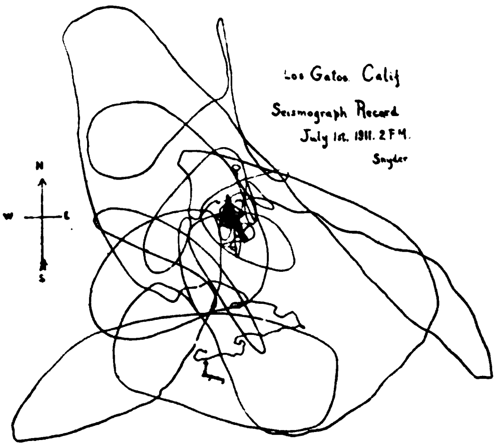
Los Gatos, by Irving H. Snyder.—Time, approximately 2 p.m., Pacific standard time. A Los Gatos jeweler who was on the summit of the Coast Range when the shock occurred gives the time as exactly two o'clock. A large pendulum clock in a local jewelry store stopped at 2:00:03 p.m. P.S.T.

Duration, close to twenty seconds.

This was the severest earthquake Los Gatos has experienced since April 18, 1906. The record of the duplex seismograph shows that the shock began with very few preliminary tremors, the movement quickly rising to the maximum, which was almost three inches, in a northwest to southeast direction, after which it slowly diminished.

A roar, lasting about three seconds immediately preceded the shock. Most persons who heard it, say it came from the south, but a few contend that it was from the north.

Crockery and bric-a-brac was broken in many houses, and plaster fell in some instances. About twenty chimneys were badly cracked and a few overthrown. A portion of a fire-wall was also thrown down. At the railway station a train of loaded gravel-cars was set in motion and ran from a switch on to the main track.



Duplex pendulum record of the earthquake at Los Gatos. By I. H. Snyder.
The figure represents the movement of a point.
From a photograph, and reduced one half diameter.

Intensity, R.F. scale VII.

Coyote, by E. C. Templeton.—In the Santa Clara valley the shock apparently reached its greatest intensity south of San Jose, in the region about Coyote. At this place a small frame house was shaken from a foundation about four feet high, plastering was shaken down from all the plastered houses, a concrete retaining wall at the bridge a little west of the town was cracked off, many windows were broken, clocks were stopped, and dishes, books, and other articles were shaken from their shelves. Near Coyote three county water-tanks about twenty-five feet high and strongly supported were shaken down. Three men are reported to have been shaken from their feet while at work in the fields. Persons who experienced both this shock and the earthquake of April 18, 1906 declare that while this one was of shorter duration, it was the more intense of the two. The intensity by the Rossi-Forel scale was probably VIII at this point, and it is possible that it was somewhat higher.

Madrone, by E. C. Templeton.—The shock seems to have been somewhat less severe at Madrone than at Coyote. The inhabitants were startled, a large number of dishes were jarred from their shelves, and clocks were stopped, but no serious damage was done. One lady claims to have been shaken from the chair she was sitting on, and a man reported that he had difficulty in keeping his feet while standing on the ground. A gage reading was taken on Coyote Creek two and a half miles northeast of Madrone, but it showed no change in the flow. The intensity of the shock at Madrone was apparently about VII R.-F.

Boulder Creek, by W. S. Rodgers.—I was sitting at my desk here in the "Mountain Echo" office writing at the time of the earthquake, the hour being about two o'clock p.m. It commenced with an almost imperceptible tremble that gradually increased in force for a few seconds until there were two or three quite sharp and strong final oscillations that caused the wooden frame building in which I was at the time to crack and snap in the joints most viciously. So pronounced was the cracking that I thought the large panes of glass in the front windows would surely break. By this time I had risen, intending to leave the building, when the quake seemed to stop as suddenly as it had commenced. I did not feel any light final oscillations after the hard shock, as some claimed to have experienced.

In my office nothing was thrown down, but in some of the grocery stores about town a few canned and bottled goods were thrown from the shelves. No serious loss or damage was suffered from this cause, however. In the store immediately opposite my office something was thrown from above on to some dishes, a few of which were broken. I heard of no damages in any dwelling house, and there were no chimneys broken off or thrown down in town. As near as I could discern the vibrations were from east to west.

My eldest son, who is a civil engineer, was surveying near some buildings on a farm about a mile north of town. He said that before he felt the vibrations of the quake he plainly and distinctly heard a pronounced rumble like thunder in the southeast, the interval being several seconds, he thought. I did not hear this noise, but of course this could easily have been swallowed up in the noises of the town. Moreover, I was inside at the time. My son says that all of his surveying party heard the rumbling sound before the quake. He also told me that the vibrations seemed to be from southeast to northwest, according to his experience. Also that there were some short vibrations that seemed to be perpendicular. The only other item of interest, perhaps, I could add was that here in town the startled people rushed from the business places to the street when the hardest shocks came.

Morgan Hill, by E. C. Templeton.—At Morgan Hill a few windows were broken, clocks stopped, and dishes were shaken from their shelves. A tank and windmill about forty feet high were tilted several degrees out of plumb toward the west. A few chimneys are also reported as having been shaken down, and at a low sag in the valley floor two telegraph poles are said to have been broken off at the ground, the tension of the wires preventing them from falling. The intensity of the shock here was probably about VII R.-F.

San Martin, by E. C. Templeton.—Apparently the intensity of shock at San Martin was not more than VI R.-F. It was plainly felt, and broke a few dishes by jarring them from their shelves. No other damage is reported.

Santa Cruz, by E. C. Templeton.—The shock was not nearly so severe as that of April 18, 1906. Many of the people were alarmed and ran out of the stores and houses, and some clocks were stopped. No damage is reported. Its intensity was probably VI R.-F.

Watsonville, by W. R. Radcliff.—When the quake of July 1st came I was in the act of winding the clocks of our coin safe in the Bank of Watsonville. The half-ton door of the safe was open, its direction being from southwest to northeast. The safe stands on a concrete floor seven feet in thickness, and inside of a concrete, railroad-iron and steel vault with walls two feet in thickness. The shock caused the heavy door to sway perhaps a quarter of an inch, and the swaying continued several seconds. Though the door swayed perceptibly the stacked gold coin within the safe was not disarranged. We have had lighter shocks which threw over the gold stacks within the safe.

While the shock was long and suggestive of the 1906 shock, no damage was done to buildings, no glass was broken, no fissures appeared, no landslides occurred, and but few clocks were stopped. The shock was preceded by a long roaring sound similar to the noise which preceded the shocks of 1906.

Coalinga, by R. E. Collom.—On Saturday, July 1, 1911, at approximately 2 p.m., the writer noted a very feeble earth shock at the Coalinga pump station of the A. P. L. Co., three and one-half miles north of the town of Coalinga. The writer was sitting indoors at a desk at the time. The shock seemed to occur in two phases several seconds apart. The principal directions of motion seemed to be northerly and southerly. The only visible effect of the shock was the gentle movement of the surface of some water in a glass jar. This shock was felt by a number of persons seated indoors in Coalinga.

Los Angeles, by Clarence B. Osborne.—The earthquake of July 1, 1911, was felt in Los Angeles, but it was so light in effect that only a few people in the higher buildings noticed it and but few of these realized what it was.

I was on the sea coast south of Redondo at the time of the quake and did not feel it, but my attention was called to a number of small rock slides that were started simultaneously on the steep bluffs at the time, as the air was still and there did not seem to be any reason for them.

The sandy beach line from Del Rey south to Redondo is spotted here and there with small patches of thick black crude oil. This is washed ashore from a seepage out at sea and is supposed to be along a fault line that is parallel to the coast and about half a mile out from the shore.

On July 4, 1911, I was along the coast from Del Rey to Redondo and found between high and low tide-marks that the beach was almost black with these patches of crude oil. I have visited this coast line at different times for the past five years, after heavy storms and high tides, and have always paid attention to the crude oil, but I have never seen any similar amount of oil as was on the beach after the earthquake of July 1, 1911.

MICROSEISMIC MOVEMENTS.

By H. Benndorf (Graz)

(Translated by C. Abbe, Jr., from "Geologische Rundschau" I, 183-186; Leipzig. 1910)

1. Hecker, O.: Ueber die Ursachen der mikroseismischen Bewegung. Aus seismometrischen Beobachtungen in Potsdam in der Zeit vom 1. Januar bis 31. Dezember 1905. Berlin, 1906.
2. Klotz, O.: Mikroseisms. Jour. Roy. Astron. Soc. Canada. 1908. p. 195.
3. Galitzin, B.: Ueber mikroseismiche Bewegungen. Beitr. z. Geophysik, 10: 86. 1909.
4. Schneider, R: Ueber die pulsatorischen Oscillationen (mikroseismische Unruhe) des Erdbodens im Winter 1907/08 in Wien. Mitteil. Erdbeben-Komm. N. F. Nr. 35. Wien, 1909.
5. Linke, F.: Die Brandungsbewegungen des Erdbodens und ein Versuch ihrer Verwendung in der praktischen Meteorologie. Abhdl. k. Ges. d. Wiss., Göttingen. N. F. VII. 1909.

In addition to the true earthquakes and disturbances of a local nature such as those caused by street traffic, etc., the seismograph also records a peculiar species of very small waves known as "pulsatory oscillations," "microseismic unrest," "pendulum unrest," etc. A large number of prominent seismologists have already studied these disturbances with some care, but without being able to arrive at any generally accepted explanation of the phenomenon. Accordingly the Permanent Commission of the International Seismological Association, in session at the Hague in September 1907, appointed a special committee (Kommission) and charged it with the study of these microseismic movements, in order to solve if possible the questions as to their nature and cause.

The writer does not know whether or not this Special Committee has made its report; but in any case a number of papers bearing upon this problem have been published in the past few years, and they have essentially aided our understanding of the phenomenon.

Hecker differentiates four kinds of microseismic disturbances, according to the records at the Potsdam station, as follows:

1. Movements of very short period, up to 4 seconds;
2. Movements with a period of about 7 seconds;
3. Movements with a period of about 30 seconds;
4. Movements with a period of 1 or more minutes.

The movements of the first kind are due to vibrations set up by traffic, factory machinery, etc. The movements of the fourth kind are of such rare occurrence that at present nothing more can be said as to their nature.

The waves having a period of seven seconds occur principally in the winter and sometimes continue for one or more days. Investigations during 1904 and 1905 showed that the 7-seconds waves are independent of local winds, local pressure-gradients, and also of changes in temperature and pressure. On the other hand it was definitely established that these waves depend upon the maximum pressure differences over the whole of Europe, and that increasing pressure differences correspond to increasing amplitudes in the crustal movements. Comparisons with the state of the sea on the coast of Norway reveal but slight increase in crustal movements with an increasing sea.

In contrast to the 7-seconds waves, the 30-seconds waves show a very distinct relation to the local wind force and pressure-gradients. Hecker therefore concludes that the 30-seconds waves are due to the friction of the wind on the earth's surface, but he reaches no definite conclusion as to the cause of the 7-seconds waves.

Klotz, using the material collected at the earthquake stations at Ottawa during 1907 and 1908, arrives at conclusions similar to those of Hecker. The microseismic movement (5- to 6-seconds waves) is most frequent and strongest during the winter (October), and slightest during the summer (July, August); local winds are without influence, as are also temperature changes. He could find but one definite connection between these disturbances and meteorological conditions, viz: when a *low* is located over the Gulf of St. Lawrence the microseismic movements always occur, and they are particularly strong if a ***high*** lies south of the *low* and is situated over the Atlantic coast.

Galitzin's observations were made at Pulkova during the end of 1907 and the beginning of 1908. His results wholly confirm Hecker's investigations. Galitzin departs from Hecker's view in ascribing a yet more local origin to the 30-seconds waves (i. e., the movement of the ground due to swaying of trees in the wind, the pressure of the wind against walls of the building). He adopts Wiechert's recent views regarding the short-period microseismic movements (4- to 6-seconds waves), viz., that these are the proper vibrations of the earth's crust as it rests upon an internal magma, which are dampened out to a large extent by the ocean swell.

Schneider subjected the material from the Vienna station for the winter of 1907-08 to a specially searching analysis. He found the most frequent waves to have a period of about 6 and a mean amplitude of 0.003mm actual movement of the ground, the vertical component of the waves being markedly smaller than the horizontal component. Schneider adopts Wiechert's view and brings forward the following reasons in its support: local winds, as well as pressure distribution, are without influence on the movements; storms on the Atlantic cause strong movements only when they send a swell against the coast. Schneider finally carries out the interesting experiment of computing the simultaneous disturbances at Hamburg, Strassburg, and Vienna, and finds that the amplitude of the waves decreases considerably with the distances from the Atlantic ocean.

Linke has studied these problems the most thoroughly of all, and even the title of his paper indicates that he also holds to Wiechert's hypothesis. His observational material comes from Apia (1905-06). This station, located in the midst of the Pacific ocean. enables him to investigate the connection with surf and swell in a manner not possible for the mainland stations. His investigations lead him to the indubitable conclusion that the microseismic movements in Samoa (by the way, they are notably more intense there than at the mainland stations) are caused by the surf. This conclusion is especially convincing, since, in addition to the statistical summaries, he brings forward detailed investigations of the effects produced by individual storms.

The general results of the works reviewed may perhaps be summed up as follows:

The microseismic vibrations of short period (about 6 seconds) are independent of the local influences of the weather conditions; a necessary but not adequate condition for their occurrence is the existence of a marked *low* over the ocean. Among the hypotheses so far advanced, that by Wiechert is the only one that well explains the observations. It may then, at present, be safely assumed that in these microseismic oscillations we have to do with vibrations set up by the ocean surf. It remains for future investigations to show the nature of these vibrations and how far they are modified by the geological peculiarities of the place of observation.

BOOK REVIEWS.

Boletin del Servicio Sismolojico de Chile II, ano de 1909, por el Conde Montessus de Ballore, Director del Servicio Sismolojico. Santiago de Chile, 1910.

This second volume of the reports of the Seismologic Service of Chile by Count de Montessus de Ballore contains 305 pages of text and 23 plates.

The first 238 pages of the bulletin are taken up with the observations made by the service and its volunteer assistants during the year 1909.

At page 239 the following conclusion is given in regard to the possible use of the barograph as a seismoscope:—

"In the preceding number of this bulletin the question of the availability of the barograph as a seismoscope is discussed. It is noted that this instrument when shaken sometimes gives abnormal records that are readily distinguished from its ordinary oscillations. These records, however, are very untrustworthy. A study of the records for 1909 fully confirms this view. . . . The following conclusion is reached: the barograph cannot be used as a seismoscope, although it registers certain shocks, under conditions that are peculiar and not now understood. The conditions cannot be investigated on account of the closing toward the end of 1909 of the Oficina del Tiempo de la Quinta Normal de Santiago, which contained the barograph, the records of which were studied in these bulletins."

There follows a resumé of the seismologic observations, made by the French expedition to the antarctic regions of Chile under Dr. Charcot.

A Wiechert pendulum was installed for fifteen days on Deception Island, an extinct volcano. Here were noted only tremors of doubtful origin, the records being very like those caused by wind. Besides, the frequent movements in the ice pack must have caused small tremors, the diagrams of which are of unusual forms.

During the remaining nine winter months on Petermann Island various seismic phenomena were registered. Two important seismograms were obtained, one of doubtful value, the other corresponding to the shock of October 22d, whose focus was 650 kilometers from the *Pour-quois-pas?* in a direction nearly northeast or southwest, but in this case without its being possible to determine which. If it were toward the northeast the point would be in the ocean and well away from the western entrance to the Straits of Magellan, while if it were toward the southwest the shock would have had its focus in the very centre of the antarctic continent.

The seismographic results of the expedition are thus commented upon by the distinguished director of the Seismological Service of Chile: "The supposed but false interdependence between seismic and volcanic phenomena has such deep roots in public opinion that I use the occasion to meet it once more with experimental evidence. It will be observed in fact that the region visited by the French expedition is full of the remnants of volcanoes, and yet its seismic equilibrium has been shown. Besides, the Scott expedition to Ross Sea kept a Milne seismograph in operation for eighteen months near the celebrated volcano Erebus without its registering a single local earthquake. This stability of the antarctic continent is borne out also by the negative results obtained in Tierra del Fuego by the ***Romanche*** in the winter of 1882, by meteorological observations made for years at the Argentine Station of Ushuwaia, and finally by those made at Punta Arenas since 1852."

The bulletin contains a large number of engravings showing seismograms and the installations of the various instruments in the central observatory at Santiago, where, by the way, the instruments are mounted in a tunnel made in basaltic trachite in the Cerro Santa Lucia park at Santiago. The first plate in the series in an interesting attempt to show seismicity by latitude. The peculiar narrowness of Chile as compared with its length lends itself remarkably well to this method of representation. One of these diagrams has been constructed from observations made during the year 1909; this places the highest seismicity for that year between latitudes 26° and 27° and the next lower between 32° and 33°. The same plate shows the seismicity for a hundred years, from 1810 to 1909, with its highest development between 33° and 34°, and the next lower between 32° and 33°.

J. C. BRANNER.

· BULLETIN SEMESTRIEL DE L'OBSERVATOIRE MÉTÉOROLOGIQUE DU SÉMINAIRE-COLLÈGE ST. MARTIAL, PORT-AU-PRINCE, HAITI, Janvier-Juin, 1910; Juillet-Décembre, 1910.

The bulletin of the Observatory of the Collège St. Martial under the direction of our colleague, Professor J. Scherer, Director of the

Observatoire Météorologique, forms part of the series of bulletins published in the "Annales Météorologiques" of Austria and of France since 1888. The bulk of the bulletins is necessarily given up to the usual comprehensive meterological observations, but at pages 51 to 54 and from 149 to 150 are lists of earthquake shocks reported from the various stations in Haiti during the year 1910, and of the microseisms recorded by the one seismograph at Port-au-Prince.

Only one shock having an intensity of VI or more was noted during the year 1910, and that occurred on August 30. The highest intensity (VII) was reported at Jérémie.

J. C. B.

CATALOGO DE LOS TEMBLORES (MACROSEISMOS) SENTIDOS EN LA REPUBLICA MEXICANA Y MICROSEISMOS REGISTRADOS EN LA ESTACION SEISMOLOGICO CENTRAL, TACUBAYA, D. F., DURANTE EL SEGUNDO SEMESTRE DE 1909. PAREGONES DEL INSTITUTO GEOLOGICO DE MEXICO, t. III, No. 8, pp. 435-496. Director, JOSE G. AGUILERA, Subdirector, JUAN D. VILLARELLO. Mexico, 1911.

The data given in this valuable report are contained in formal tables, which include dates of the shocks recorded, the instruments and their components, intensities and phases, duration, amplitude, focal distance, and occasional notes or additional observations.

In the list of the macroseisms it is noted that during the period covered by the report there was one shock on July 30th that reached an intensity of VII at Acapulco and Chilapa. At Acapulco the shaking is said to have lasted one minute, several buildings were destroyed, persons injured, and there was a general panic. At most places from which it was reported, however, the shock had an intensity of only II or III. Many of the shocks reported were accompanied by subterranean sounds.

A distinction is made in the report between the shocks reported at the central seismologic station at Tacubaya near the City of Mexico and those observed elsewhere. The Tacubaya station is provided with two Bosch-Omori instruments with a ten kilo weight and with a Schmidt trifilar gravimeter. Most of the shocks in these tables are recorded as having their origin within a radius of 1000 kilometers. Out of the 176 earthquakes mentioned in the Tacubaya table, 11 were at a distance greater than 1000 kilometers.

J. C. BRANNER.

THE BALUCHISTAN EARTHQUAKE OF 21ST OCTOBER, 1909. By A. M. HERON, B.Sc., F.G.S. Records of the Geological Survey of India, vol. xli, pp. 22-35, 1911.

The earthquake (intensity IX, Rossi-Forel scale) occurred at about 5:12 a.m., in a district from forty to fifty miles to the north of Jacobabad, and resulted in the loss of 231 lives and much damage to the villages of Bagh, Bellpat, and Shahpur. As in most strong earthquakes, the onset of the shock was sudden. Mr. Heron traces three isoseismal lines from the evidence of damaged buildings. They are remarkable for their great elongation from northwest to southeast, the innermost being fifty-seven miles long and only eight miles wide. The central area is covered by thick alluvial deposits, but it lies in the gigantic festoon of the Marri and Bugti Hills, by which the north and south trend of the Baluchistan ranges is interrupted. Mr. Heron considers that the earthquake was probably caused by a movement along a reversed fault, although no trace of deep-seated displacement is visible at the surface.

C. D. (Geol. Mag.)

SEISMOLOGY, TERRESTRIAL MAGNETISM, AND GRAVITY. By OTTO KLOTZ, LL.D. Report of the Chief Astronomer (of Canada), 1909. Appendix No. 1. Ottawa, 1911.

Of this report pages 26 to 52 are devoted to seismology. The Göttinger nomenclature at page 26 is followed by five pages of tables giving data regarding shocks recorded at the Earthquake Station, Dominion Astronomical Observatory, at Ottawa, Canada. From January 1, 1908, to March 31, 1909, sixty-two shocks were recorded, only one of which was of Canadian origin, and that in the vicinity of Ottawa.

Aside from the value of the long list of recorded earthquakes, which goes without saying, this report is noteworthy for its frank and clear statement of many of the difficulties encountered by seismologists, and for its discussion of seismologic problems.

At page 34 reference is made to the "difficulty we encountered when trying to read on the seismogram the arrival of the long wave." Again, "it is believed that the discordances obtained for the velocity of the long waves are mostly or wholly attributable to the uncertainty of identifying, midst the complexity of longitudinal and transverse waves and their reflections which precede, the arrival of the surface or long waves."

In this connection one is reminded that "There are now some two hundred earthquake stations distributed over the earth, and the seismograms furnished by them are far from homogeneous, and far from equal merit and value for studying the geophysical problems for which they are obtained. The first order of precision to be aimed at is that of time. Seismology demands now that the time recorded should be accurate within at least one second. As standard time is now so widely distributed by telegraph, there seems no reason why the time of every earthquake station should not be controlled by the time from some astronomical observatory."

At page 35 the author calls attention to the enormous area of archaean rocks in Canada and to the bearing of the geology on the occurrence of earthquakes, adding that, "This is probably the largest area of archaean rock on the earth, being closely followed by the Scandinavian peninsula and Finland. As earthquakes are intimately associated with the age of rock formation, the more recent being more subject to disturbances than the older ones, we may say that, broadly speaking, the vast area above referred to will always be fairly free from earthquakes."

He adds further that "The more or less severe, but not destructive, earthquakes that have visited eastern Canada are all associated more or less directly with the 'Great Champlain and St. Lawrence fault,' running from the gulf up the river to Quebec and then curving southwesterly to Lake Champlain."

He quotes at length from an old manuscript account of an earthquake that is said to have occurred in Canada, February 5, 1663. And not the least of Dr. Klotz's services to seismology is his directing attention in a dozen words, to the ridiculously extravagant language often employed in such descriptions. The account says the mountains "were torn from their beds and thrown upon others, leaving immense chasms in the places from which they had issued," and "mountains were overthrown, swallowed up by the gaping, or precipated into adjacent rivers, leaving in their places frightful chasms or level plains." "Near St. Paul's bay . . . a mountain about a quarter of a league in circumference, situated on the shore of the St. Lawrence, was precipitated into the river, but, as if it had only made a plunge, it rose from the bottom and became a small island." It is added that this earthquake "continued from February to August, that is to say, more than six months, almost without intermission." Of all this, and a lot more of the same kind, Dr. Klotz simply says "that the narrators of the above anticipated the sensationalism of our 'yellow' journals by two and a half centuries."

There follow lists of shocks reported by the press in 1908 and 1909. Under the head of microseisms many interesting matters are discussed, which a lack of space will not permit us to quote here. The paper should be in the hands of every student of seismology.

J. C. B.

THIRTIETH REPORT OF THE STATE GEOLOGIST OF NEW YORK. John M. Clarke, Director. Albany, April 15, 1911.

At pages 21 to 24 is a brief report on the seismological station maintained at Albany under the care of the State Geologist. Twenty-three shocks were recorded at the station during the year ending September 30, 1910, as compared with nineteen during the previous year, making a total of seventy-seven recorded since the instruments were installed in March, 1906.

The heaviest shock during the year had a maximum amplitude of 30 mm. and continued for more than an hour. It originated in or near Iceland.

The station is equipped with two Bosch-Omori horizontal pendulums of 11.283 ks.

SEISMOLOGICAL NOTES.

The Panama Canal and earthquakes.—The liability of the Panama Canal to injury by earthquake has been a matter of conjecture and of some speculation. It is interesting to note that the Isthmian Canal Commission has installed a Bosch-Omori 100 kg. seismograph at the Ancon Observatory. The altitude of the station is 80 feet and its coordinates, lat. 8° 57′ 16″ N., longitude 79° 31′ 4″ W. Greenwich mean time is used. We have received two reports of earthquakes. Seismic record No. 1 shows a disturbance of February 15, 1911, first preliminary tremor 11h 50m 48s, long waves beginning 11:52:15 and ending 11:54:00. Both the north-south and east-west components are given. There appears, however, to be no record of vertical motion. The approximate distance of the origin of the shock, 200 miles. Probable direction, north. Seismic record No. 2, dated April 10, 1911, shows a disturbance beginning at 6:42:30. The distance of the origin not given.—ALEXANDER G. MCADIE, Professor, U. S. Weather Bureau.

Earthquakes at Unalaska.—Professor George Davidson sends us the following interesting note under date of July 3, 1911: "In looking over the Alaska Coast Pilot of 1869, I came across this statement, taken from Russian authorities, of the number of earthquakes that had been recorded at Unalaska by Weniaminof, as follows:

Year	Earthquakes	Thunderstorms
1825	7	1
1826	5	2
1830	2	0
1831	4	4
1832	7	6
1833	4	4
1829 and 1834	3	0
	—	—
Total	32	17

After this time there is no record."

Earthquakes at San Jacinto.—The newspapers report two earthquake shocks at San Jacinto, California, on August 11, 1911. The first is said to have occurred shortly after 10 o'clock in the morning, the other at 3:40 p.m. It is said to have been distinctly felt throughout Riverside, Orange, San Bernardino, and Los Angeles counties. No damage is reported to have been done.

Some of the difficulties.—The following letter from a member of the Society seems to express so well some of the difficulties of a seismologist that we take the liberty of quoting it. The BULLETIN OF THE SEISMOLOGICAL SOCIETY is meant to meet the needs referred to by the writer.

"Personally I feel the need of a journal of communication with others having charge of seismographs. I feel the need of knowing what others are doing in the handling of their instruments or improving them. I want to know how they solve their difficulties of one sort or another, and I wish to tell some of my own. I want a paper of some sort coming to hand frequently, and promptly giving me some notion as to whether pendulum swayings registered at my station are noted at neighboring stations, and how far away, and so on. Except for a few of us who are running a postal-card exchange of data concerning earthquakes registered at our respective stations, we hear usually nothing more about the matter until the International Strassburg 'Katalog' comes out four years after the earthquake in question!

"I'd like to know who has a seismograph, where it is, and what kind of information I may get from the officer in charge, if any, etc. Some of us are in the dark, perhaps, as to methods of getting the best results from our instruments, as to mathematical formulæ, as to this and that which we may be expected to know."

Dr. Klotz has lately made some interesting and valuable observations upon the conductivity of shocks by limestones. Blasting done with dynamite in shaly limestones at a distance of 10,000 feet, or 3050 km., from the seismographs of the astronomical station at Ottawa, produced no effect on the seismogram. Dr. Klotz observes, however: "If there was any (trace), it was masked by the very small microseisms that were present on that day. Besides the presence of the minute microseisms two other causes militated against obtaining a record: one, the lack of compactness of the rock over that distance, and the other, the very rapid oscillations that would be set up, to which the seismograph could not well respond."—Report of the Chief Astronomer, Appendix I, pp. 25-26. Ottawa, 1911.

Members of the Seismological Society are urged to report any earthquake they may observe to the "Secretary of the Seismological Society, Stanford University, California." Notes should be sent as soon as possible after the earthquake.

The following form may be used:

1. Place and date of the earthquake.
2. Time and duration of the shock, giving hour, minute and second, if possible.
3. State whether the time used is standard time.
4. Was the observer in the open or indoors; lying down, sitting, standing, or walking ?
5. Effects of the shock: rattling of windows, rattling of dishes and bottles, cracking of plaster, falling of chimneys.
6. State whether the shock was accompanied by noise; describe it.
7. Was the shock generally observed ?
8. Were people alarmed by it ?
9. Any other notes that may be of interest.
10. Name and address of the observer.

Books and papers for review in this BULLETIN should be addressed to the "Secretary of the Seismological Society of America, Stanford University, Calif."

Seismologic stations that send out monthly or other reports are requested to send copies to the "Secretary of the Seismological Society of America, Stanford University, California."

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE SEISMOLOGICAL SOCIETY OF AMERICA, SEPTEMBER 16, 1911.

The meeting was called to order by President Branner at 3:30 p.m. in Room 1404, Merchants' Exchange Building, San Francisco. Directors Branner, Burckhalter, McAdie and Townley were present.

The minutes of the meeting of the Board held on April 6th were read and approved.

The death of Professor Josiah Keep, a member of the Society, was announced by the Secretary.

The resignations of two members were accepted.

Twenty-nine new members, whose names are subjoined hereto, were recommended by the president and secretary and elected to membership in the Society. Thirteen institutions were placed on the list of subscribers.

By a motion duly seconded and carried Professor George Davidson was elected an honorary member of the Society.

By motions duly seconded and carried the actions of the Secretary in starting a commercial account with the Bank of Palo Alto and in granting a hundred reprints free of charge to Mr. Wood were approved.

It was decided, by a motion duly seconded and carried, that hereafter only fifty reprints, without covers, be granted free to contributors to the BULLETIN.

The matter of exchanges was again brought up, and it was the opinion of the directors present that the Society should not establish an exchange list, and that no discounts should be allowed to news agencies.

The Board adjourned at 4:45 o'clock.

S. D. TOWNLEY, Secretary.

NEW SUBSCRIBERS.

Board of Fire Underwriters of the Pacific: San Francisco, Cal.
Bureau of Mines (Director of): Washington, D. C.
Chief Astronomer: Ottawa, Canada.
Cornell University (Library of): Ithaca, N. Y.
Dartmouth College (Library of): Hanover, N. H.
Erdmagnetisches Observatorium und Erdbeben-Station: Munich, Germany.
Geological Survey (Librarian of): Ottawa, Canada.
Michigan College of Mines (Library of): Houghton, Mich.
Mount Holyoke College (Library of): South Hadley, Mass.
Ohio State University (Library of): Columbus, Ohio.
The University of Chicago (General Library of): Chicago, Ill.
University of Missouri (General Library of): Columbia, Mo.
University of Pennsylvania (Library of): Philadelphia, Pa.

NEW MEMBERS ELECTED SEPTEMBER 16, 1911.

B. A. Baird: San Francisco, Cal.
Count de Montessus de Ballore: Santiago, Chile.
Bernard Bienenfeld: San Francisco, Cal.
P. Carmody: Port-of-Spain, Trinidad.
Rich. Cirvera, S. J.: Tortosa, Spain.
T. W. Edgewood David: Sydney, Australia.
A. J. Eddy: Berkeley, Cal.
N. K. Foster: Oakland, Cal.
Andrew Greig: Broughty Ferry, Scotland.
Santiago de la Huerta: Habana, Cuba.
Fred. H. Lahee: Cambridge, Mass.
Homer Laughlin, Jr.: Los Angeles, Cal.
Samuel Crocker Lawrence 2nd: Medford, Mass.
E. R. Lyman: Portland, Ore.
Mary Isabel McCracken: Stanford University, Cal.
D. W. Ohern: Norman, Okla.
W. W. Orcutt: Los Angeles, Cal.
J. R. Pemberton: Balcheta, Rio Negro, Argentina.
Wm. B. Phillips: Austin, Texas.
Wm. G. Reed: Berkeley, Cal.
J. S. Rossiter: Pasadena, Cal.
J. Scherer: Port-au-Prince, Haiti.
Edgar C. Smith: Riverdale, Cal.
W. A. Spaulding: Los Angeles, Cal.
E. C. Templeton: Palo Alto, Cal.
Beach Thompson: Menlo Park, Cal.
Burton M. Varney, Portland, Maine.
Chester W. Washburne: Buenos Aires, Argentina.
Edward Wigglesworth: Cambridge, Mass.

ROSSI-FOREL SCALE OF EARTHQUAKE INTENSITIES

I. **Microseismic shock**: recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds; the shock felt by an experienced observer.

II. **Extremely feeble shock**: recorded by several seismographs of different kinds; felt by a small number of persons at rest.

III. **Very feeble shock**: felt by several persons at rest; strong enough for the direction or duration to be appreciable.

IV. **Feeble shock**: felt by persons in motion; disturbances of movable objects, doors, windows; creaking of ceilings.

V. **Shock of moderate intensity**: felt generally by everyone; disturbance of furniture, beds, etc., ringing of swinging bells.

VI. **Fairly strong shock**: general awakening of those asleep, general ringing of house bells; oscillation of chandeliers; stopping of pendulum clocks; visible agitation of trees and shrubs; some startled persons leave their dwellings.

VII. **Strong shock**: overthrow of movable objects; fall of plaster; ringing of church bells; general panic, without damage to buildings.

VIII. **Very strong shock**: fall of chimneys, cracks in walls of buildings.

IX. **Extremely strong shock**: partial or total destruction of some buildings.

X. **Shock of extreme intensity**: great disaster, buildings ruined, disturbance of the strata, fissures in the ground, rock-falls from mountains.

OFFICERS OF THE SOCIETY

John C. Branner...President
Harry F. Reid...First Vice-President
Andrew C. Lawson...Second Vice-President
Alexander G. McAdie...Third Vice-President
Sidney D. Townley...Secretary-Treasurer

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Auditing Committee:—G. D. Louderback, W. F. Durand, Otto von Geldern.

Publication Committee:—J. C. Branner, A. C. Lawson, H. F. Reid, S. D. Townley.

Scientific Committee:—A. C. Lawson, J. C. [illegible], W. J. Humphreys, Otto Klotz, F. L. Odenbach, H. F. Reid, J. B. Woodworth.

(The first named in each committee is the chairman. The president is *ex-officio* a member of all committees.)

NOTICE

Section 3 of Article XIII of the Constitution of the Society reads as follows: "The Scientific Committee or Council shall consist of seven members of the Society who shall have general supervision of all matters of scientific interest. It shall have power to designate sub-committees on publication, on establishment of seismological stations, and on such other matters as shall be directly connected with the collection and investigation of scientific data, or the dissemination of information."

Sections 1 and 2 of Article VI of the By-Laws read as follows: "The annual dues shall be two dollars, payable within two months after election to membership, and thereafter annually in advance on April 1st. . . . Any member upon the payment of twenty-five dollars shall become a life member, and shall be exempt from the further payment of dues."

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Volume I Number 4

Bulletin of the Seismological Society of America

PUBLICATION COMMITTEE

John C. Branner, Stanford University, Cal.
Andrew C. Lawson, Berkeley, Cal.
Harry F. Reid, Baltimore, Md.
Sidney D. Townley, Stanford University, Cal.

DECEMBER 1911

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1911

Major Clarence Edward Dutton

The Bulletin of the
Seismological Society of America

VOL. I DECEMBER, 1911 NO. 4

MAJOR CLARENCE EDWARD DUTTON.

By J. S. Diller.

Major Clarence Edward Dutton, the first seismologist of his country, was born May 15, 1841, at Wallingford, Conn. His parents were Samuel Henry and Emily (Curtis) Dutton. At Ellington, Conn., he received his preliminary education, and in June, 1856, entered Yale, where he graduated in 1860 with the degree of A. B., at the age of nineteen. April 18, 1864, he married Emeline C. Babcock, of New Haven, Conn.

He was appointed Adjutant of the 21st Connecticut Volunteers in September, 1862, and the following year, March 1, promoted to captaincy. In 1864 he was transferred to the ordnance corps of the Regular Army and served through the remainder of the war. While assigned to the Watervliet Arsenal in 1865 he began his scientific studies, which, as he informs me, took two directions, and both were pursued with ardor. The first was invertebrate paleontology, under the guidance of Hall and Whitfield. The second was the study of steel, in co-operation with Alexander L. Holley of the Bessemer Steel Works, of Troy.

At the end of five years he was transferred to Frankford Arsenal, Philadelphia, and thence to Washington, D. C. Being cut off from immediate contact with steel, his thoughts concentrated upon geology, especially upon the physical side of the subject. He became a member of the Philosophical Society of Washington in 1872, and became acquainted with Professor Henry and Professor Baird, who took great interest in him. Through the former and Major Powell he was induced to consent to a detail for duty with the Powell Survey, beginning May 15, 1875.

He devoted ten years to the study of the great plateau region of the West, and published his results in the three reports entitled "The Geology of the High Plateaus of Utah" (4),[1] "The Tertiary History of the Grand Canyon District" (5), and "Mount Taylor and the Zuñi Plateau" (11). The plateau region of the West is remarkable not only for the simplicity of its geological phenomena but also for their variety and the enormous scale of their exposure.

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[1] The numbers in ( ) refer to list at end of this article.

Dutton's general conclusions are summarized in the closing chapter of the report on Mount Taylor and the Zuñi Plateau. Although contributing much to the geological history of the region, he evidently dwells with greater pleasure on the physical problems, and remarks in describing the facts that "Not a trace of systematic plication has yet been found there," referring especially to the Zuñi part of the plateau region. "The terms anticlinal and synclinal have almost dropped out of the vocabulary of the western geologist. The strata are often flexed, but the type of flexure is the monocline."

"The country at large shows no traces of a wide-spread, universal horizontal compression; on the contrary, it discloses the absence of such stress. We seem here to get nearer to the real nature of the process which has built the mountains. Shorn of that extreme complexity which confuses and bewilders us in more highly developed structures, the great central facts and the true essence of the mechanical processes involved become much clearer. The mountains of the West have not been produced by horizontal compression, but by the action of some unknown forces beneath, which have pushed them up."

The greatest problems of physical geology, according to Dutton (13), are: First, What is the potential cause of volcanic action? second, What is the cause of elevation and subsidence of restricted areas of the earth's surface? third, What is the cause of the foldings, distortions, and fractures of the strata?

The first two of these he regarded as being without satisfactory explanation, and for the third he proposed a solution in elucidating his theory of isostasy. After having shown that the contractional hypothesis is quantitatively insufficient and qualitatively inapplicable in explaining the folding of the earth's crust, he presented in a modified form and greater detail the theory propounded many years ago by Babbage and Herschel. It was pointed out that the unloading of the land by erosion and the loading up of the sea floor by deposition resulted in a force which tends to push the loaded sea bottoms inwards upon the unloaded land horizontally, a force of the precise kind that is wanted to explain the origin of systematic plication.

This view of the essentially isostatic condition of the earth has been in recent years most ably advocated, and in fact practically demonstrated by Prof. John F. Hayford.[2]

Dutton began the study of the volcanic problems early in his geological career, and his first papers in the Geological Survey (2) pertained to volcanic products. In his study of the plateau region he had abundant opportunity to observe an extensive and profoundly interesting series of complete and dissected volcanic as well as plutonic masses. In 1882 he visited the Hawaiian Islands to study Kilauea, Mauna Loa and their other great volcanoes (8) before beginning his survey of the great volcanic field of northern California and Oregon, where in 1885 he made a special study of Crater Lake and recognized its similarity to the great Calderas of Hawaii (12).

He returned to military duty in September, 1890, and went to Central America and Lake Nicaragua. In 1891 while on duty at San Antonio, Texas, he made frequent excursions to the volcanoes of Mexico, and writes:[3]

> "The subject of volcanoes and volcanic action had become of paramount interest to me, and I resolved to grapple with the problem. All existing theories seemed to me insufficient, and I became a confirmed skeptic as to the cause of volcanic action.
>
> "From 1875 to 1885 I continued to labor with the problem, but could only conclude that the cause was the local accumulation of heat, yet no reason for it appeared. For a time, it seemed possible that the intrusion of basaltic masses among the sedimentaries might lead to chemical reactions which would furnish the necessary heat, as Prof. Reginald A. Daly so ably proposes in his recent theory of volcanic action. But after long reflection I could not accept that view and concluded that as science then stood a solution was impossible and it would be necessary to wait until some discovery should put another face upon the subject.
>
> "A discovery of prime importance—that of radioactivity—was made in 1897, which seemed to furnish the explanation of the necessary amount of heat near the earth's surface."

His final conclusions on volcanoes and radioactivity were presented to the National Academy of Sciences, April 17, 1906 (16).

Dutton made a special study of the Charleston earthquake in 1886 and devised a new method of ascertaining the depth of the earthquake focus, and measured with greater accuracy than ever before attained the rate at which an earthquake wave is propagated. His isoseismal method of computing the depth of focus involves the determination of two critical points, first, the epicentrum, and second, a point on a radius from the epicentrum at which the intensity of shock diminishes most rapidly. A line drawn around the epicentrum through the points of most rapid change of intensity Dutton called index circle, and pointed out that the focal depth is the product of the radius of the index-circle multiplied by the square root of three.

---

[2] The Figure of the Earth and Isostasy. Coast and Geodetic Survey Report, 1909. Also, Supplementary Investigations in 1909 of the Figure of the Earth and Isostasy. Coast and Geodetic Survey Report, 1910.

[3] Letter October, 1911.

The Charleston earthquake had two foci. The depth of the Woodstock focus he computed to be twelve miles and of the Rantowles focus nearly eight miles. The determination of the index circle, as Dutton himself recognized, is a matter of difficulty and the conclusions must be regarded as only approximate.

Concerning the rate of propagation he remarks (14, p. 211) "after a careful study of all discussions of this particular problem, based upon the observations made in other earthquakes, I have no hesitation in declaring my opinion that the result from the Charleston earthquake far outweighs them all and that all preceding determinations of this quantity are wholly invalid or wide of the mark." The average speed of propagation of the Charleston earthquake Dutton determined from three groups of observations to be 5,184 meters per second. He devoted much consideration to the nature and mechanism of the earthquake wave motion.

Since his retirement, February 7, 1901, with abundant time at his disposal, his active mind has been much employed in the further study of volcanoes and earthquakes. His latest publication on the latter subject is a book entitled "Earthquakes in the Light of the New Seismology," a most comprehensive, instructive and useful contribution to popular knowledge. To quote his own words:

"Chapter I sets forth the nature of an earthquake according to the modern concepts. It defines the technical terms used in discussion, and describes the action taking place on the surface of the ground during a quake of great energy. Chapter II is a general discussion of the causes of earthquakes. Two causes are recognized, apparently quite distinct, though possibly they may have interrelations not yet recognized. The first cause is volcanic; the second is that force which is presumed to be always active in disturbing the rocks which form the outer shell of the earth, resulting in the building of mountains, the folding and shearing of the strata, and the elevation and depression of the earth's crust. Thus we have two groups of quakes, volcanic and tectonic. They have in many cases distinct characteristics, and these are described in Chapters III and IV."

The more important instruments used in seismometry are described in Chapters V and VI, and Chapter VII discusses the details of seismic vibratory motion and explains the four kinds of waves with which the inquiry deals.

A chapter (VIII) is given to the amplitude and period of vibration, and two chapters (IX and X) to the subject of intensity. The chapter on the variation of intensity points out the method of computing the depth of origin of an earthquake wherever observations sufficient in number and accuracy can be obtained.

"The speed of propagation of seismic vibrations is then treated (XI and XII). No specific problem in connection with earthquakes has been more diligently investigated, and few are so difficult as this. It is only very recently that definite results upon this question have been reached. The chief trouble has been the great complexity of the waves generated by an earthquake, their different rates of propagation, and the difficulty of separating one kind from another. Nor was it known until recently that some kinds of waves are propagated through the earth-mass, while others go around it.

"Since the speed of propagation depends wholly upon the ratio of elasticity to density, it becomes an index of those properties in the materials which compose the earth's interior. Chapter XIII is given to the discussion of this aspect of the subject."

The subject of earthquake distribution or seismic geography is treated in two chapters (XIV and XV) and the final chapter (XVI) is devoted to seaquakes.

Major Dutton is a member of many scientific and other organizations, among which may be mentioned the Philosophical Society of Washington, the American Geographical Society, the Academy of Political and Social Science, the Geological Society of America, the National Academy of Sciences, and the Seismological Society of America.

In his writings Major Dutton has a most vigorous and impressive style. His choice of words is of the best, euphonious, simple but full of force and interest. His phraseology is direct, winning the attention of the reader and holding it throughout. He may be justly considered one of the best writers of popular geological science of his day. He resides at Englewood, New Jersey.

List of Major Dutton's Most Important Geological Publications.

1. A Criticism upon the Contractional Hypothesis.
   Am. Jour. Sci., 3d ser., vol. VIII, pp. 113-123. Aug. 1874.
2. Report on the Lithologic Characters of the Henry Mountain Intrusives, in G. K. Gilbert's Report on the Geology of the Henry Mountains.
   Pp. 61-65. 1877.
3. Critical Observations on Theories of the Earth's Physical Evolution.
   The Penn. Monthly, May and June, 1876. (Reviewed in *Am. Jour. Sci.*, 3d ser., vol. 12, pp. 142-145.)
4. Geology of the High Plateaus of Utah. 1880.
   United States Geographical and Geological Survey of the Rocky Mountain Region. J. W. Powell in charge. 307 pp. and atlas.
5. Tertiary History of the Grand Canyon District.
   U. S. Geol. Survey Mon. 2, 264 pp. 1882.
6. Physics of the Earth's Crust; by Rev. Osmond Fisher.
   Am. Jour. Sci., 3d ser., vol. XXIII, pp. 283-290. 1882.
7. The Physical Geology of the Grand Canyon District.
   U. S. Geol. Survey 2d Ann. Rept., 1880-81, pp. 47-166. 1882.
8. Hawaiian Volcanoes.
   U. S. Geol. Survey 4th Ann. Rept., 1882-83, pp. 75-219. 1884.
9. The Effect of a Warmer Climate upon Glaciers.
   Am. Jour. Sci., 3d ser., vol. 27, pp. 1-18. 1884.
10. The Volcanic Problem Stated.
    Abstract in *Bull. Phil. Soc. of Washington*, vol. VI, pp. 87-92. 1884.
11. Mount Taylor and the Zuñi Plateau.
    U. S. Geol. Survey 6th Ann. Rept., 1884-85, pp. 106-198. 1885.
12. Crater Lake, Oregon, a proposed National Reservation.
    Science, vol. 7, pp. 179-182. 1886.
13. On some of the Greater Problems of Physical Geology.
    Phil. Soc. of Washington Bull., vol. XI, pp. 51-64. Read April 27, 1889.
14. The Charleston Earthquake of August 31, 1886.
    U. S. Geol. Survey 9th Ann. Rept., 1887-88, pp. 209-328. 1889.
15. Earthquakes in the light of the new Seismology.
    Pp. 314. 1904. G. P. Putnam's Sons, New York.
16. Volcanoes and Radioactivity.
    (Read before the National Academy of Sciences, April 17, 1906.) Pamphlet 12 pages—published by the *Englewood Times*, Englewood, N. J., for the author.

U. S. GEOL. SURV., WASHINGTON, D. C., November 14, 1911.

EARTHQUAKE EPICENTERS

By Otto Klotz

As soon as an earthquake has been well recorded by a seismograph, the first question that presents itself is, Where was it?

So far, no one has succeeded in answering his own question completely save Prince Galitzin by means of the record of his own-devised seismographs, with magnetic damping and galvanometric registration.

It is outside of the scope of the present paper to enter into a discussion of the records and theory of different kinds of seismographs.

The problem before us is, to locate geographically the epicenter of an earthquake. At the recent International Seismological meeting at Manchester, England, Professor Wiechert of Göttingen in his address spoke of three methods in vogue: the one of Prince Galitzin, the one of Professor Zeissig, and the one of the writer. That of the latter we shall briefly describe.

In modern seismographs we are able, when a good record has been obtained, to note the time of arrival of the first and second preliminary waves, that is, of the longitudinal or compressional waves, and of the transverse or distortional waves, designated as the *P* and *S* waves by our international nomenclature. From geographically well-known earthquakes we know the transmission times fairly well for these waves for various distances, from which time curves, inaccurately designated as hodographs by some writers, have been constructed, notably those by Wiechert and Zöppritz. Professor Zeissig has interpolated the *S* — *P* curve of these latter for intervals of 10 km. up to 13,000 km., representing a time difference of *S* — *P* of 12m 56s. The time-scale for a seismogram is supposed to be sufficiently open to read the individual second. The method to be described is the *"Stereographic Method."*

In this projection the eye, or projecting point, is supposed to be at the pole of the primitive circle. The particular merit of this projection is that all circles, great circles as well as small circles, except those whose plane passes through the eye, are projected on the primitive plane as circles. The data that we utilize for locating the epicenter are the distances Δ, from three stations, besides the geographical co-ordinates of the latter.

We imagine a circle described on the sphere about one of the stations with a radius of Δ, converted into arc, 10,000 km. = 90°. The epicenter obviously lies somewhere on this circle. Similarly we describe a circle about another station with its proper radius. This latter circle will intersect the former in two points, one of which is the epicenter. If now we again describe a circle about a third station, the ambiguity of the two points will be determined and the common intersection of the three circles, the epicenter, found. It is desirable that the three stations be fairly far apart. Let us make the preliminary projection. In Fig. 1, O is the point of projection, AB the trace of the primitive plane upon which the projections are made. P is a station, having the latitude φ. $PF = PE$ are arcual radii or distance, Δ, to epicenter converted into arc. FE is then the orthogonal projection of the small circle about P. This circle projected on to the primitive plane will cut it in H and K, *i.e.*, HK is its diameter, and the middle point of HK, or I, is the center of the projected circle, giving HI and IK as radii. NI is the distance from the pole from which our circle is to be described, as we shall see presently.

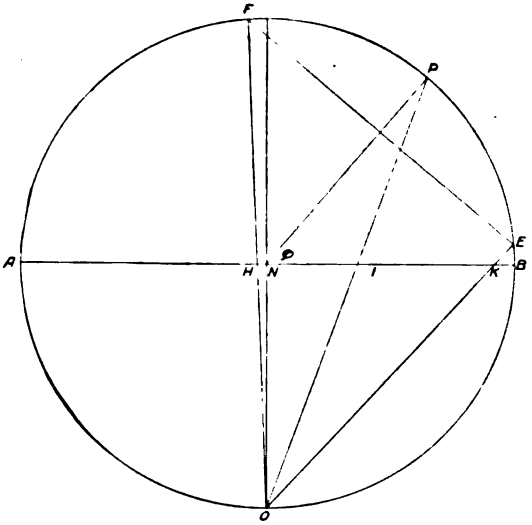

FIG. 1.

HI and NI are the two quantities that we require for the final construction and location of the epicenter, and as seen above, they can be found graphically if the scale is not too small, say not less than 10 cm. for the radius of the circle AOB. It is more convenient, however, to take the quantities from a table such as I computed for twenty-seven earthquake stations and published in the May-June, 1911, number of the *Journal of the Royal Astronomical Society of Canada.*

From mathematical considerations, if we call the distance PF, PE equal to Δ in arc, HI the radius $= r$, and NI the polar distance $= d$, ($NO =$ unity) then

$$d = \frac{\cos\phi}{\sin\phi + \cos\Delta}, \quad \text{and} \quad r = \frac{\sin\Delta}{\sin\phi + \cos\Delta}.$$

We shall next proceed to the final construction, taking as example the Turkestan earthquake of January 3-4, 1911, and the published records of Strassburg, Pulkowa and Ottawa, that is we obtain Δ for each station from the time difference $S - P$. We thus have

Strassburg $\phi = 48^\circ\ 35'$, $\lambda = 7^\circ\ 40'$ E, $\Delta = 5300$ km. $= 47^\circ\ 42'$
Pulkowa $\phi = 59^\circ\ 46'$, $\lambda = 30^\circ\ 20'$ E, $\Delta = 3690$ km. $= 33^\circ\ 13'$
Ottawa $\phi = 45^\circ\ 24'$, $\lambda = 75^\circ\ 43'$ W, $\Delta = 9800$ km. $= 88^\circ\ 12'$

Computing now d and r, or interpolating them from my above published tables, we get for

Strassburg $d = 4.65$, $r = 5.20$
Pulkowa $d = 2.95$, $r = 3.16$
Ottawa $d = 9.45$, $r = 13.45$

in terms of radius = 10 cm.

In Fig. 2 we have the primitive circle with 10 cm. radius. It may be mentioned here that we had special graduated forms engraved as shown reduced in Fig. 2. We proceed to draw the meridian lines for each station, being the longitude from 0°, or Greenwich. d is laid off from the pole along the respective meridian, and gives the center of the circle of which r is the radius. This circle we proceed to describe, or an arc of it. This is done for each of the three stations and it will be found that the three arcs will intersect, if not at a mathematical point yet very close to each other. Theoretically, if the earthquake emanated from a point and our Δ's were absolutely correct, then the intersection with careful drawing would practically represent a point for the epicenter. As a matter of fact, however, the earthquake or breakdown is not a point, but more properly a plane, so that we can scarcely expect our intersections to have a common point, but instead to form a minute triangle of which we take the center of gravity as the most probable point of the greatest intensity of the seismic disturbance.

From the distance of the pole to this point in our construction we obtain the latitude of the epicenter, for this distance is equal to tan (45° — ½ φ_0), where φ_0 is the latitude of the epicenter. The longitude is read directly on our circle, simply by drawing the meridian line from the pole through the point or epicenter. In our diagram the distance from the pole is 4.28 cm., representing the tangent of 23° 10′, hence $\varphi_0 = 43° 40′$, and the longitude we find to be 78°20′ E. The epicenter of this earthquake has thus been found to be in

$$\phi = 43° 40', \quad \text{and} \quad \lambda = 78° 20' \text{ E.}$$

Prince Galitzin found by his method, the geographical co-ordinates to

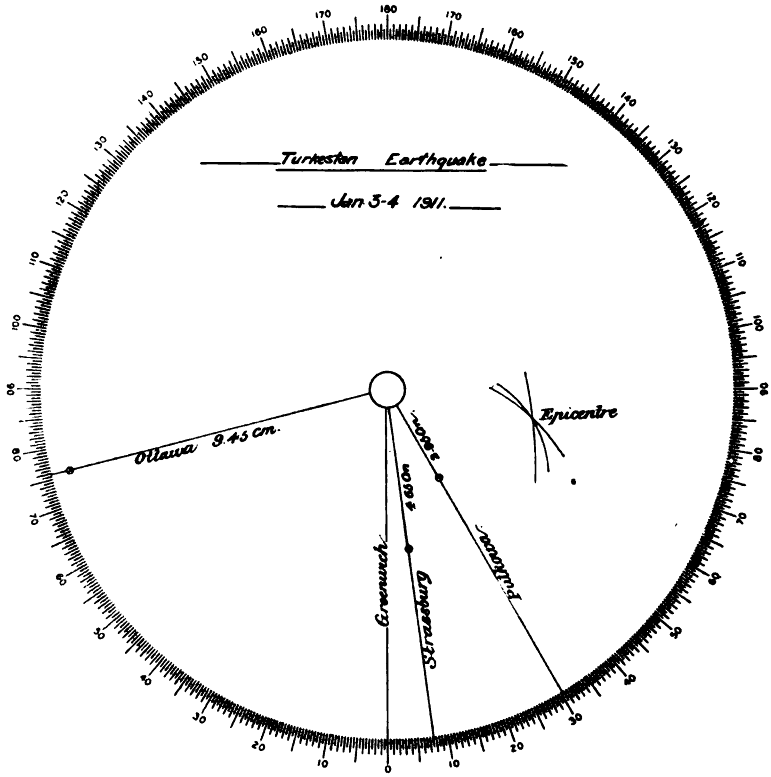

FIG. 2.

be $\varphi = 43° 14'$, $\lambda = 78° 24'$, a very close agreement. The epicenter has thus been found in a simple and expeditious manner, and with an accuracy quite in keeping with the data. It is to be observed that it is expected that the drawing is made with care and accuracy, otherwise considerable discrepancies may arise in the result. I find that I can get quite good results with a circle of radius 10 cm. One of 20 cm. might be for some perhaps more serviceable, but we must not lose sight of the accuracy of our data, otherwise we are cracking walnuts with a sledge-hammer. With the present conditions I think we are doing pretty well if we feel fairly sure of our half degree in the location of our epicenter.

We must pay attention to the algebraic sign of $\cos \Delta$, and also of $\sin \varphi + \cos \Delta$, whereupon depends the direction along the meridian line that d is measured. Cases may occur in which the algebraic summation of $\sin \varphi + \cos \Delta$ becomes very small, and hence d and r inconveniently large for plotting. In such a case another station may be chosen.

As the absolute time at some, perhaps many, stations is not very accurately known, thereby affecting the time record, it will be noted that in the above method the absolute time does not enter, but only the time difference $S - P$, in short the method is independent of the time correction. However, for other reasons it is highly desirable that all stations have their time accurate within a second.

From our stereographic projection we may also deduce the azimuth of the epicenter. The azimuth is the angle at the station between the meridian and the tangent to the great circle passing through the station and epicenter. For describing the circle we have three points, the station, its nadir and the epicenter. The station is projected on the meridian line at the distance of $\tan (45° - \frac{1}{2}\varphi)$, and the nadir at, and in the opposite direction, of $\cot (45° - \frac{1}{2}\varphi)$. We have thus three points cut by the circle. The three points form a triangle in the circle and the angle at the epicenter is equal to $180° - A$, from simple geometrical relations, A being the azimuth. In the figure (2) the points for tan and cot $(45° - \frac{1}{2} \varphi)$ for the three stations, and the connecting lines to the epicenter, are not drawn, to avoid confusion.

In the original drawing we find graphically for Ottawa, $A = 18°$, and solving trigonometrically the spherical triangle, pole — station — epicenter, we obtain $A = 18° 27'$.

Similarly for Strassburg we find graphically $A = 111° 30'$, computed $A = 112°5'$, and for Pulkowa, graphically $A = 97°45'$, computed $A = 97°28'$. Prince Galitzin obtains the mean, from the maximum amplitudes at the beginning of the first preliminary tremors, $A = 97°57'$.

The above azimuths are reckoned from north through east.

In some other methods the azimuth enters into the determination of the epicenter, which is not the case in the method described. It will now be shown briefly how the stereographic projection adapts itself also for plotting with azimuth and distance. We have given Δ and A. On the meridian line of any station we have three known points,

$$\frac{\cos\phi}{\sin\phi + \cos\Delta}, \quad \tan(45° - \tfrac{1}{2}\phi) \quad \text{and} \quad \cot(45° - \tfrac{1}{2}\phi),$$

as already explained. Furthermore, the angle A at the station, which gives the tangent to the circle through the station and its nadir. Hence the circle can be described having given a chord and tangent. Finally we draw an arc with radius $r = \frac{\sin\Delta}{\sin\phi + \cos\Delta}$ at the distance d from the center. Where this arc cuts the above circle is the epicenter, whose geographical co-ordinates are determined as already described.

DOMINION OBSERVATORY, OTTAWA, October 2, 1911.

THE IMPORTANCE OF DISPLACED OBJECTS IN STUDYING THE CHARACTER OF EARTHQUAKE MOTION IN MEGASEISMIC AREAS

By Stephen Taber

The displacement of objects free to move is a common phenomenon of great earthquakes, but its importance as an aid in studying the character of motion in the megaseismic area has been very largely overlooked. In recent years the establishment of seismological observatories and the perfection of sensitive instruments for recording minute movements of the earth have added much to our knowledge of those earthquake vibrations which are transmitted great distances from their origin, but as yet very little is known concerning the larger waves that are confined to the megaseismic area of earthquakes, and that are responsible for the great loss of life and destruction of property that frequently accompany them.

There are large areas of the earth's surface without seismological stations of any kind, and where severe earthquakes have occurred in the immediate vicinity of such stations they have furnished very little information concerning the motion, for the instruments, designed to record microseismic vibrations, are quickly disabled by the violence of a heavy shock, making the records so imperfect as to be useless in studying the actual motion. In the excitement attending severe earthquakes few people make accurate observations, and therefore the statements of most individuals as to the direction and character of motion are of little or no value. For these reasons, in studying earthquake motion in the megaseismic area, we are in most cases largely dependent on the circumstantial evidence furnished by the movement of liquids and the displacement of solids, such as stones, buildings, furniture and other objects.

Attempts to make use of such data, however, have usually proved unsuccessful because observers have almost always failed to distinguish between the different forms of displacement, particularly between simple translation in a straight line and overturning of the object. In the study of earthquakes this subject of the displacement of solids has not received the attention which it deserves. It was first discussed in a scientific way by Robert Mallet, the founder of modern seismology, who devoted considerable space to the subject in his paper "On the Dynamics of Earthquakes; Being an Attempt to Reduce Their Observed Phenomena to the Known Laws of Wave Motion in Solids and Fluids," which was presented before the Royal Irish Academy in 1846.[1] It was in this thesis that he first advanced the theory that earthquake movement was due to the transit of a wave of elastic compression.

In studying great earthquakes Mallet observed that many heavy bodies were displaced in the same direction, i. e., away from the epicenter, and offered the following explanation of "why a body displaced . . . is not replaced in an earthquake." The center of gravity and therefore the object itself describes an ellipse in space and the horizontal velocity is greatest at the top and bottom of the ellipse, "but when approaching the top, the inertia of the mass assists in holding it fast to its bed; while on the back stroke or when the center of gravity is returning to the bottom of the ellipse the inertia of the mass acts in freeing it from the friction or adhesion of its bed and the mass becomes shifted upon it."[2] This explanation is obviously erroneous, for as a matter of fact the pressure of the body upon the supporting surface is constantly decreasing during the upward motion and increasing during the downward motion. Later it was observed that during an earthquake different bodies, which must have been acted upon by the same outside forces, frequently moved in diametrically opposite directions, and so far as I know no one has attempted to explain this phenomenon.

During great earthquakes visible waves, having the appearance of flat surface waves on water, are sometimes seen passing with great rapidity over the surface of the land. They are not noticeable at a distance from the epicenter and are probably visible only when passing through unconsolidated material in alluvial valleys. Much of the damage wrought in the megaseismic area must be attributed to these waves, for with their large amplitude of vibration and comparatively short wave length they are necessarily very destructive to buildings and other structures. The fact that cracks have been observed to open and close in the ground during the passage of these visible waves proves that there is an important horizontal as well as a vertical component to the motion, and therefore a particle resting on the earth's surface would in general move in an elliptical path, the plane of the ellipse being vertical and parallel to the direction of wave propagation.

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[1] *Transactions Royal Irish Academy,* vol. 21. Dublin, 1848.

[2] Ibid., p. 64.

It is true that the actual motion of such a particle is not quite so simple, for it is the resultant of many simultaneous vibrations, some of which are due to reflection and refraction and which are too complicated to analyze. Investigators have repeatedly shown that during earthquakes the motion of a single particle is extremely complicated, and that the maximum movement is not always or even usually in the direction of wave propagation, but the observations on which such statements are based have been obtained during earthquakes of only moderate severity, or at considerable distances from the epicenter. It is an unwarranted assumption that the same conditions obtain in the megaseismic areas of great earthquakes, and certainly while the ground is being traversed by visible waves, of the kind just described, the motion of a wave particle must be approximately elliptical.

It will now be shown that these visible surface waves propagated from a single origin are sufficient to account for the following simple forms of displacement affecting solid bodies resting on the earth's surface:

(1) Rectilinear translation both toward and away from the origin.

(2) Rotation about a vertical axis.

(3) Overturning.

Of course there may also be any combination of these three simple forms of displacement.

(1) *Rectilinear translation.*—If a surface upon which some body is resting is given an elliptical motion in a vertical plane we may consider this motion to be the resultant of two harmonic vibrations, one vertical and the other horizontal, differing in phase by ¼ period. Let the ellipse given in Fig. 1 represent the path described by the center of gravity of the body, *AB* and *CD* being respectively the amplitudes of the horizontal and vertical components of motion. Now, if we consider the vertical vibration alone, it is seen that the velocity is greatest at *O* and becomes zero at *C* and *D*, where it changes sign; the acceleration is greatest at *D* and *C*, and zero at *O*, where it changes sign. The horizontal motion is of course similar.

The force tending to displace the body relative to the plane is due to inertia; the force tending to resist the displacement of the body is due to friction which is proportional to the pressure between the object and the supporting surface. At *O* the pressure is equal to mg where m equals the mass of the body and g the acceleration due to gravity. The pressure at any point is equal to $m\ (g + p)$ where p equals the acceleration due to the vertical vibratory motion, but p has a positive maximum at *C* and a negative maximum at *D*.* Therefore the pressure is greatest at *C* and least at *D*. It may become zero at some point between *O* and *D* if p should equal or exceed g. While the supporting surface is describing the curve from *B* to *D* the body may, if the coefficient of friction is small, become displaced toward the right relative to the supporting surface. On the other hand, if the coefficient of friction is sufficiently great, the body may remain stationary relative to the supporting surface until close to *D*, but here the horizontal velocity of the supporting surface has reached a maximum and begins to decrease, so after the body is set in motion it may move toward the left faster than the surface below and thus receive a relative displacement in that direction. Of course a body with a small coefficient of friction will move alternately toward the right and left, but the net result will be a displacement toward the right, while a body with a larger coefficient of friction is displaced in the opposite

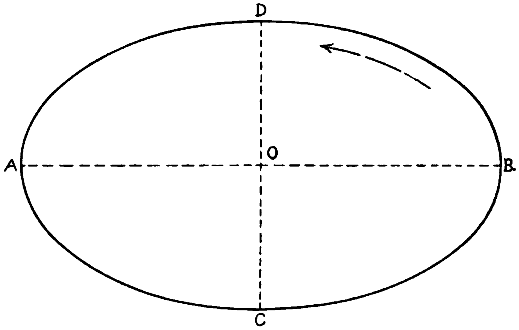

Fig. 1.

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*For a body moving under gravity the downward direction is usually taken as positive and hence downward velocity and downward acceleration, g, are also positive. If p is also taken positive downward then the author's sentence should read: "The pressure at any point is equal to $m\ (g - p)$ where p equals the acceleration due to the vertical vibratory motion, but p has a ***negative*** maximum at *C* and a *positive* maximum at *D*." If the velocity due to the vertical vibration be taken positive upward then the sentence is correct as it stands.—S. D. T.

direction. If the vertical acceleration becomes greater than the acceleration due to gravity the body may leave the plane completely for a short interval.

It is thus seen that when an object resting on the surface is subjected to vibrations causing it to move in a vertical ellipse, it may receive a permanent displacement in the direction of wave propagation if the coefficient of friction is relatively great, or in the opposite direction if the coefficient of friction is relatively small.

The fact that difference in friction is sufficient to cause bodies, subjected to the same outside forces, to become displaced in opposite directions may be illustrated by a very simple experiment. If two coins, one of which has a piece of sandpaper glued to it, are placed side by side on a flat surface, such as a book, and the latter given an elliptical motion in a vertical plane, one coin can be made to move in one direction while the other is displaced in the opposite.

An examination of several earthquake reports together with field studies made by the author at the time of the California earthquake in 1906 leads to the conclusion that this theory explains the rectilinear displacements that occur in opposite directions during earthquakes. The total displacement of a body moved during an earthquake may take place at one time or may be the sum of a number of small displacements caused by successive wave vibrations. Many examples of objects displaced in opposite directions might be cited, but one will suffice.

During the California earthquake of 1906 a stone wall supported by a series of arches resting on columns was displaced 7.75 inches, causing the capitals to overhang the columns by that amount; at the same time a heavy iron safe on the ground floor of a neighboring building rolled backwards and forwards with a net displacement in the opposite direction. This took place at Stanford University, situated four and a half miles from the fault where the earthquake vibrations originated. The wall was displaced away from the fault line and the safe toward it.

Sometimes the vertical acceleration due to earth vibrations becomes greater than the acceleration due to gravity and then heavy bodies are projected into the air. Professor Oldham describes boulders that were thrown into the air during the great Assam earthquake[3] in

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[3] Report on the Great Earthquake of 12th June, 1897. *Memoirs Geological Survey of India*, vol. XXIX, pp. 130-133.

British India, June 12, 1897. The fact that the boulders were thrown for considerable distances (two to four feet) from their original position indicates that there was also a large horizontal component to the motion.

(2) *Rotation.*—There are at least two theories that may be offered in explanation of the rotation of objects on their base when acted upon by surface waves of the kind described, and there are undoubtedly instances in which each explanation finds application.

If the center of friction does not lie in the vertical plane through the center of gravity of the body and in the direction of the motion, a couple will be formed, causing the body to rotate on its base. This theory was first proposed by Robert Mallet.[4]

If the motion causes the body to rock on its base, rotation may result whenever the point of support does not lie in a vertical plane through the center of gravity of the body and in the direction of the motion at that instant. The latter theory is due to Professor Thomas Gray,[5] but it should be noted that the explanation is not limited to bodies with a rectangular base. It may even find application in the case of bodies with a circular base, for unless the supporting surface is perfectly horizontal and the wave motion confined absolutely to one horizontal direction a slight couple will be formed which will rapidly increase after twisting has once begun.

Rotation may also be produced by two or more simultaneous non-vertical vibrations that are not in the same straight line. In recent years several authorities have come to the conclusion that most examples of rotation are to be explained on the basis of this theory. It is not necessary to assume more than one origin for these wave-vibrations, since longitudinal and transverse waves may be propagated simultaneously from a common origin.

(3) *Overturning* is one of the commonest forms of displacement in severe earthquakes. If the center of gravity of a body is sufficiently high above its base, the body, upon being subjected to any movement having a horizontal component may be upset by its own inertia. The direction of overthrow is partly controlled by the shape of the base and its orientation relative to the direction of motion at

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[4] Dynamics of Earthquakes. *Transactions Royal Irish Academy,* vol. XXI.

[5] J. Milne. The Earthquake in Japan of February 22, 1880. *Transactions Seismological Society of Japan,* vol. I, pt. II, pp. 33-35.

the instant the body begins to topple, but in the case of bodies that are equally free to fall in any direction the overthrow is invariably parallel to the line of motion. Therefore freely falling bodies, when upset by the visible surface waves of megaseismic areas, are thrown either in the direction of wave propagation or in the opposite direction.

Several investigators have attempted with varying degrees of success to use the direction of overthrow as a means of locating the epicenter. At the time of the Neapolitan earthquake of 1857, Mallet found that in the great majority of cases the direction of overthrow was in line with the epicenter. In subsequent earthquakes investigators met with less success in attempting to apply this method, and after seismographic records had been obtained showing the great irregularity of earthquake motion it was practically abandoned. The danger of assuming that the large motions of the megaseismic area are the same in character as the smaller vibrations recorded by seismographs has already been pointed out.

In his report on the great Assam earthquake, Oldham states that while within the limits of the epicenter there was no uniformity in the direction of overthrow, at a greater distance from the epicenter almost all directions of overthrow pointed towards it.[6] It is to be noted that while great care was taken to exclude objects whose direction of fall was largely controlled by their form, square pillars and chimneys were classed as free-falling bodies. Oldham reached the conclusion that the method of determining the epicenter by means of the direction of overthrow of free-falling objects is one that may be depended upon when other means fail.

Several investigators attempted to determine the principal direction of motion during the California earthquake of 1906 by means of overthrown and displaced objects, but owing to the complicated nature of the motion, the lack of uniformity in the methods used, and the fact that most individuals confined their observations to a restricted area, the information obtained was far from satisfactory.

Professor F. Omori made a statistical study of 520 overthrown monuments in the cemeteries south of San Francisco, and gives a circular diagram on which the bearings of the fallen stones are shown by radii.[7] The monuments fell in every conceivable direction, but the mean direction of overthrow was N. 76° E., i. e., away from the origin. In interpreting these data it is important to remember that a large proportion of the monuments had rectangular bases, many being oriented in the same direction, and that no attempt was made to differentiate betwen stones that toppled over and those that slid forward on their bases until they became overbalanced in one direction and fell. Moreover, these cemeteries are only about two miles northeast of the fault line. The directions of the principal motion as determined by Omori at San Jose and Chittenden were also away from the fault line, but his determinations of direction made at other points, especially those close to the fault, were not so uniform.

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[6] Report on the Great Earthquake of 12th June, 1897. *Memoirs Geological Survey of India*, vol. XXIX, pp. 354-358.

[7] Preliminary Note on the Cause of the San Francisco Earthquake of April 18, 1906. *Bulletin Imperial E. I. C. Japan*, vol. I, No. 1, Japan, January, 1907.

Mr. Robert Anderson made a detailed study of 1,000 houses in San Mateo County, all standing between two and four miles northeast of the fault line. In his conclusions he states that "the dominant directions taken by moving bodies during the course of the earthquake shock were southwest and northwest with movements northeast and southeast only second in number."[8]

In a paper published soon after the earthquake, giving the result of studies in the southern portion of the San Francisco Peninsula, I endeavored to show that the evidence furnished by displaced objects in the megaseismic zone indicated that the principal motion near the fault line was parallel to it, while at a distance of four or five miles the principal motion was at right angles.[9] The first motion was attributed to the sudden displacement of the earth's crust that occurred on opposite sides of the fault, and the second to wave vibrations generated at the fault line and propagated through the earth. From the rapid decrease in the intensity of the first motion within a comparatively short distance of the fault line it might be inferred that the horizontal displacement of the earth's surface on opposite sides of the fault, which occurred suddenly at the time of the earthquake, was greatest at the fault line and extended for only a few miles from it before dying out. This theory is confirmed by the retriangulation carried out by the United States Coast and Geodetic Survey in 1906-1907.[10]

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[8] Effects of the Earthquake on Houses in San Mateo and Burlingame. *Report of the California Earthquake Investigation Commission,* vol. I, pt. II, p. 366.

[9] Some Local Effects of the San Francisco Earthquake. *Journal Geology,* vol. XIV, pp. 303-315. May-June, 1906.

[10] J. F. Hayford and A. L. Baldwin. The Earth Movements in the California Earthquake of 1906. *Report Coast and Geodetic Survey,* 1907, Appendix 3, p. 91.

Although overturned bodies have been used with success in determining the principal direction of motion, it is believed that more accurate results can be obtained from a careful examination of objects which have undergone simple rectilinear displacement without rotation.

The character of the damage to brick and stone walls often furnishes valuable confirmatory evidence as to the direction and form of earthquake motion. When walls are acted upon by earthquake waves having two principal components of motion, one vertical and the other horizontal and in the direction of wave propagation, the character of the damage is largely controlled by the orientation of the walls relative to the direction of wave transmission. Walls that are approximately at right angles to the direction of wave transmission fall by toppling, either away from or toward the origin, and the fallen stones retain quite closely the same relative positions that they held when the walls were standing. Walls that are at right angles to the direction of wave transmission are usually destroyed by shearing stresses and fall in irregular piles, while the walls left standing frequently show 45° shearing cracks. Other conditions being equal, waves with a short wave length are more destructive to walls and buildings than those with a long wave length.

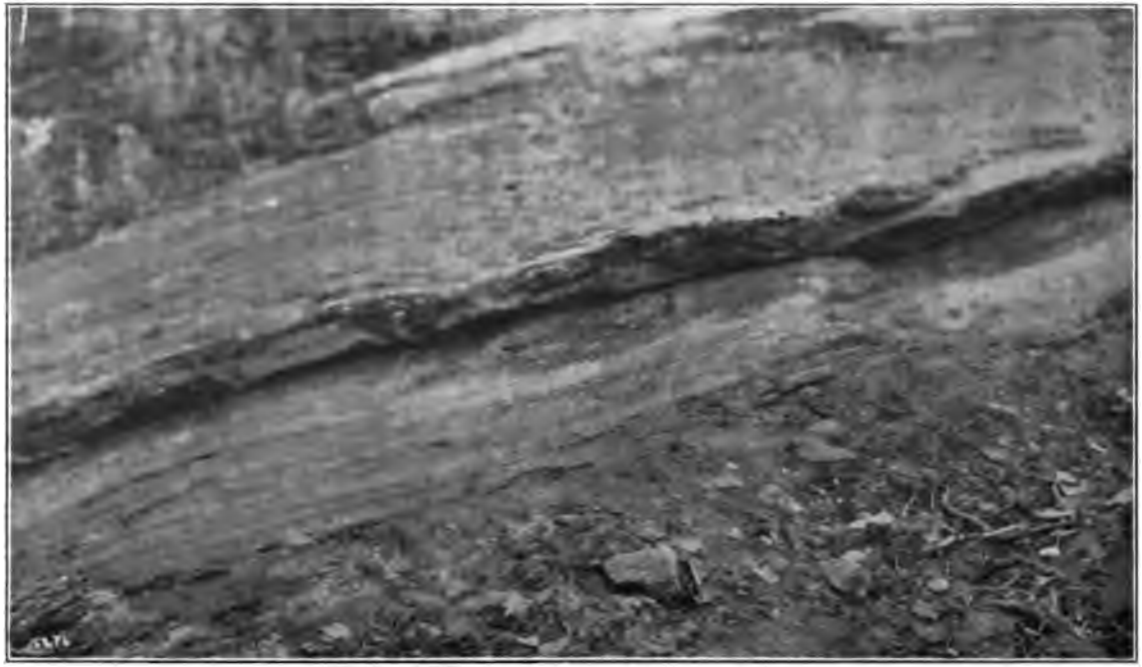
In studying earthquake motion the movements of large bodies of water or of liquids contained in vessels often furnish more accurate data than can be obtained from displaced solids, for a liquid is absolutely free to move in any direction and is more sensitive to slight vibrations. On the other hand, the evidence of motion in liquids is in most cases quickly obliterated and the investigator often has to depend on the statements of untrained observers.

When earthquakes occur near large bodies of water the shore line furnishes evidence of any changes in the relative elevation of the land surface. The great sea-waves that frequently accompany severe earthquakes are due to a sudden vertical displacemnt of the bottom of the ocean. Some geologists have stated that earthquake waves traveling over a land surface may, upon striking the sea border, thrust the waters off shore, causing a return wave which overwhelms the coast, but it is very doubtful if they ever originate in this way, for it would necessitate an earthquake of almost inconceivable intensity. In recent years many severe earthquakes have originated close to the coasts and even under the ocean without being accompanied by large sea-waves.

When a sudden vertical displacement occurs over any considerable portion of the floor of the ocean, a surface wave is generated which advances upon the coast, and this is followed by succeeding waves diminishing in magnitude until the disturbance dies out. If the displacement of the ocean floor is one of relative elevation, the crest of the wave that is generated will reach the coast first and the ocean will suddenly encroach on the land area, but if the displacement is one of relative depression, the trough of the wave will first reach the coast, causing the ocean to recede from the shore and then return. Descriptions of great sea-waves usually state that the ocean first withdrew from the land and then returned with great destructive effects. This indicates that depression of the ocean floor is more common than elevation.

These large surface waves are not as a rule perceptible to ships at sea, for they are very flat when passing over deep water. The shock that is often felt by ships is due to longitudinal waves that have been transmitted through the water or through the earth and water.

Conclusions.—In conclusion it is suggested that our knowledge of earthquake motion in megaseismic areas might be greatly increased if investigators, in making field studies of future earthquakes, would give greater attention to the displacement of solids, the movements of liquids, and the effects of the shock on walls and other simple structures. In studying displaced objects care should be taken to note the exact location of the object relative to the epicenter and to distinguish between the different forms of displacement. Not only would a better knowledge of the earthquake waves peculiar to megaseismic areas be of scientific interest, but an accurate determination of the amplitudes and wave lengths would be of practical assistance in designing structures to withstand severe earthquakes, for intensity of shock measured in terms of acceleration, though one of the most important, is not the only factor to be considered.



Fault scarp 3¼ inches high on glaciated surface of slate, near Banning, Ontario

ON SOME POST-GLACIAL FAULTS NEAR BANNING, ONT *

By ANDREW C. LAWSON

The region north of the Great Lakes is one of exceptional seismic stability. Although earthquakes are of daily occurrence in some part or another of the earth's crust, we rarely if ever hear of one originating in that quarter. Earthquakes are familiar phenomena on the Pacific coast. On the Atlantic slope and in the Mississippi valley, while they are not so frequent, they are sometimes violent. But to the north of the lakes there appears to be an absence of those stresses which find relief in rupture of the solid crust and so give rise to the jars or vibrations which we know as earthquakes. Such vibrations doubtless affect this region from time to time, but they are for the most part but the echos of shocks occurring in other regions, and so far as our knowledge goes indigenous shocks are few and far between and feeble.

This stability of the region, moreover, appears to be of ancient date, even as geologists reckon time. It reaches back almost to the Cambrian; for in the post-Cambrian rocks up to and including the Cretaceous, which encircle the great central Archaean terrane, or which remain as outliers upon its surface, there are but few evidences of those dislocations or faults from which earthquakes are generated.

In view of this well known stability which characterizes the region, I was somewhat startled one day during last summer to literally stumble upon some small fault scarps upon a glaciated surface of Archaean rocks.

The locality at which they occur is in western Ontario on the line of the Canadian Northern Railway at a point about five miles west of Banning.[1] The rocks here are dark gray, phyllitic slates, distinctly bedded and evenly fissile in planes parallel to the bedding. The strike of the rocks is N. 81° E., and the dip is northerly at an angle of 65°. These rocks are exposed in a smoothly glaciated surface which

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* Published by permission of the Director of the Geological Survey of Canada.

[1] To be more exact, the locality is twenty-two telegraph poles west of mile post 164 on the south side of the track.

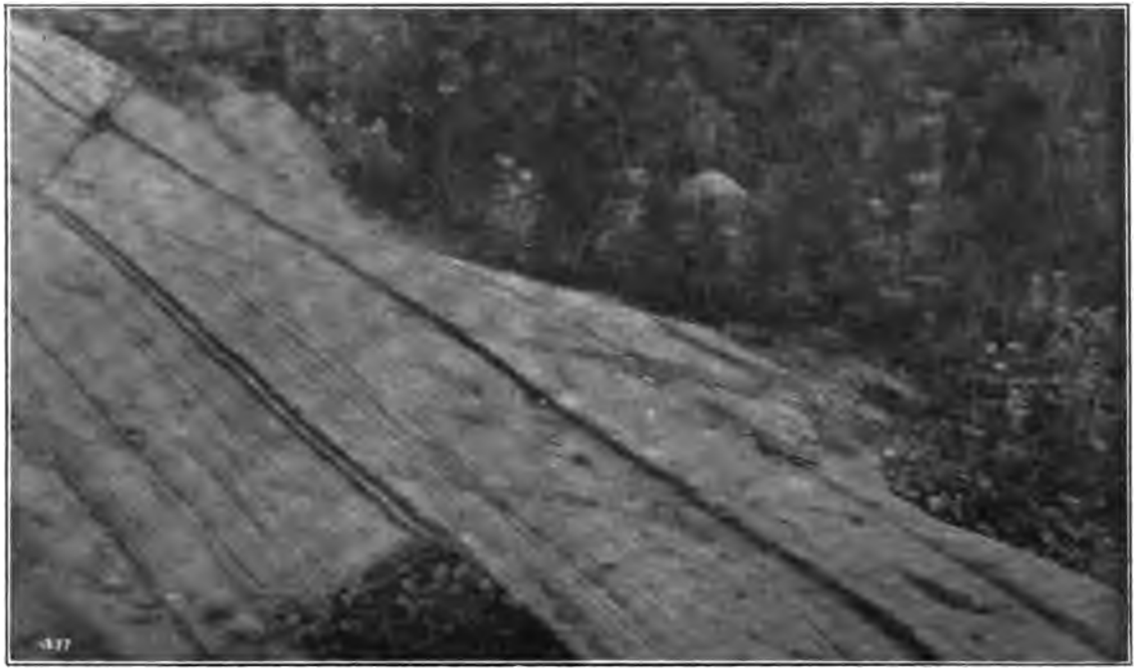
slopes down quite gently from south to north. The area exposed is only about a quarter of an acre, and it owes its exposure to the fact that the glacial drift which mantles the surface generally has here been stripped away in the course of railroad construction. Up to the time of the building of the railroad the surface was protected from erosion by a thin veneer of drift. As a result of this protection the glacial striae and grooves which everywhere score the surface have been perfectly preserved; and the fault scarps to be described owe their sharpness and escape from degradation in some measure to the same protective influence.

The glacial striae are constant in direction over this surface, and their course is N. 20° E.

This glaciated surface is dislocated by a series of reverse or overthrust faults. The fault plane in most of these is coincident with the cleavage of the slates, and since this dips to the north the result is a series of southerly facing and overhanging scarps, inclined to the horizon at 65°. The edge or crest of the up-thrust block is thus rather acute, being about 25°, and this acute edge is usually perfectly sharp and unworn except for artificial breaks. The re-entrant angle at the base of the scarp, where it meets the horizontal surface of the next lower block to the south, is equally sharp. In no case could any fault breccia or gouge be detected even on a microscopic scale; nor was any well defined slickensiding observable, although in some cases the surface of the scarp appeared to be smoother than the ordinary cleavage face and even to have a faint polish.

In every case observed, the movement on the faults appeared to be in the direction of the dip, or to have no horizontal component except that normal to the strike. This could be determined by observing the displacement of particular striae or grooves. On the up-thrust block, the striae, which make an angle of 61° with the strike of the faults, extend out to the very brink of the scarp, and on the adjacent block to the south the striae pass in under the overhanging scarp and abut against its base.

These fault scarps are small but numerous. The highest one measured 3¾ inches vertically and the others range down to one-eighth of an inch in height. In a distance of 66 feet across the strike, twenty-four scarps were counted and as the faulted surface passed beneath the drift on both sides of this, there is every reason to suppose that there are many more than could be observed.



Small fault scarps on glaciated surface of slate near Banning. One of the scarps has a stepped effect and another is jogged by an oblique joint.

The spacing of these parallel fault scarps, their vertical height and their exposed length are given in the following tabulation in which the order is from north to south.

Distance		Height	Exposed Length	
Feet	Inches	In inches	In feet	
0		¾	15	
3		1	50	
3	9	½ to ¾	40	dies out to east
1	5	¼	40	
4		½	20	
3		¼ to ¾		diffused at west into cracks
5	Group of 6 scarps	¼ to 1	25	
6		1½	60	
1	6	½	40	
2	3	1½	40	
4		1⅛	15	
2		1	20	
3		¾	30	
2	6	½	25	
1		⅝	25	
5		1	20	
1	5	¼	10	
8		3¾	35	
9		2¼	15	

The average vertical height of the scarps is about .9 inch and the average width of the moved blocks between the faults is 2.75 feet. In one case the block between two fault planes is a fraction of an inch wide, and one scarp is about twice as high as the other, giving the effect of a stepped scarp. One fault fades away in a series of vague cracks, and one has an upthrow which varies from ¾ inch to nothing at its east end. One fault on meeting an oblique joint at an acute angle is jogged along the joint and is continued westward on another plane a few inches south, leaving a dropped wedge between the eastern segment of the fault and the joint, which thus becomes an oblique fault.

Besides the faults parallel to the cleavage and bedding, there is one transverse fault with a strike of N. 8° W., and an easterly dip of 85°. The upthrow here is 1¼ inches on the east side, thus conforming to the overthrust habit. This transverse fault is exposed only for a short distance, so that its relation to the longitudinal or strike faults could not be observed.

The time between the retreat of the ice and the present at which the faulting occurred cannot be determined. The sharp, chisel-like edges of the scarps and the entire absence of any degradation would at first blush suggest a date much closer to the present than to the glacial epoch; but this inference has little force in view of the fact that the surface has until within a few years past been protected by a veneer of glacial drift, and the sharpness of the profiles may be due rather to this circumstance than to the recency of their formation. It seems probable, however, that the state of stress in the rock indicated by the faulting still exists.

Having described the facts in regard to these interesting features, it may be well to consider briefly their significance from a tectonic and seismic point of view. If these post-glacial faults near Banning were the only ones known the effort to interpret their significance would be limited to the circumstances above narrated. But some features of a similar character have been described in other regions, and by instituting comparisons we may arrive at suggestions as to the causes underlying their development that might not occur to one familiar only with a single instance.

Near the city of St. John, N. B., Matthew[2] has described quite similar faults dislocating the glaciated surface of black slates. Here the faults are also numerous and closely spaced, and are reverse or thrust faults with an upthrow of from a fraction of an inch to a few inches. Although the relation of the faults to the strike of the rocks is not clearly stated, it appears that they are for the most part parallel in strike and dip to the cleavage of the slates, and that there are occasional oblique or transverse faults, just as there are near Banning. The appearance of the faulted surface shown in Matthew's photograph is in its essential features identical with that near Banning.

Chalmers[3] a few years later described dislocations of the glaciated surfaces of slates at a number of localities in southeastern Quebec. Here again the faults are nearly all overthrusts of small upthrow and close spacing, apparently parallel to the cleavage of the slates. But in two cases Chalmers mentions blocks that have been thrust above the general level 6 feet and 5½ feet, respectively.

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[2] Movements of the Earth's Crust at St. John, N. B., in Post-glacial Times. *Bulletin Natural History Society, N. B.*, No. 12, vol. III, p. 34, St. John, 1894. Also *American Journal Science*, XLVIII, 1894.

[3] *Geological Survey of Canada, Annual Report*, vol. X, 1897, pt. J, pp. 9-12.

At a later date Woodworth[4] described similar post-glacial faults at various localities in eastern New York and quoted a description published as early as 1843 by Mather, who appears to have been the earliest observer of these interesting features. The faulting described at these localities is all of the same type as that near Banning. They all occur in slates, they are numerous and closely spaced, and are thrust faults of very small throw parallel to the cleavage. The aspect of the faulted surface as it appears in the photographs is again the same as that at Banning. Woodworth also describes similar faults at Attleboro, Mass., which occur in bedding planes of sandstones and shales devoid of slaty cleavage, and cites C. H. Hitchcock's description of similar faults in slates near Littleton, N. H.

In the discussion of these faults Matthew, Chalmers and Woodworth interpret them as manifestations of orogenic forces and correlate them with the older deformation of the regions in which they occur. There can be no doubt but that they represent a relief from compressive stresses within the rocks in which they occur, but I desire to raise the question whether we are quite justified in referring these stresses to the order of forces which we class as orogenic. The stresses which give rise to these faults may possibly be very superficial and in no way connected with those deeper seated forces which deform the earth's crust in a large way. It is at least noteworthy that we have in these cases to deal with a peculiar type of faulting which is almost wholly confined, so far as our knowledge goes, to slatey and shaley rocks. The close spacing of the faults, the distribution of the movement, the small amount of overthrust in each particular fault, and their confinement to soft, relatively plastic rocks, suggest that they are perhaps due to stresses connected with a volume change near the surface of the rocks concerned.

Such a volume change might be due to a variety of causes. For example, an increase of volume might be due to hydration of the slates freshly exposed by glacial scouring, or to an absorption of gases by such freshly exposed surface; or, change of volume due to relief of the ice load may have induced compressive stresses which would naturally find relief in overthrust faulting; or again, the temperature changes involved in the removal of the glacier would necessarily induce an expansion which would find expression in the weaker rocks and might be within the elastic limits of the stronger; or weaker rocks such as slates and shales might yield to stresses due to the expansion of neighboring stronger and more elastic rocks. The maximum summer temperatures, in so far as they affect the surface rocks, would be effective in inducing a state of compressive stress. If we suppose the temperature to rise from 0° C. in glacial time to 15° C. in post-glacial, this increment would give an internal pressure of over 2,300 lbs. to the square inch, which would in itself be sufficient to cause slates to be overthrust on their cleavage planes and to crush softer rocks. Any of these causes or any combination of them appear to me to have the tendency to produce the effects here discussd as post-glacial faulting. And while I do not here attempt to discuss the operation of these forces in a quantitative way, I hesitate to ignore them and I cannot, therefore, follow Matthew and Woodworth in their reference of these faults to true orogenic forces without at least raising the question as to other possible modes of origin. I am inclined, in the absence of a full and satisfactory discussion of the subject, to regard them as superficial phenomena arising from certain physical properties and behavior of the rock itself, and not due to forces applied to it from below. Further, it seems probable that the only seismic significance that such faulting can have, if it be superficial, is that it may afford an explanation in part of the microseisms so commonly recorded on seismograms. Moreover, it seems to me in view of the opinion just expressed that the discovery of these recent faults does little damage to the reputation which the region has so long enjoyed for seismic stability.

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[4] Post-glacial Faults of Eastern New York, *Bulletin* 107 *New York State Museum*, 1907.

Apart from the origin of these faults is the question of their geomorphic significance. Becker has suggested, indeed he has asserted, that the deformation of the earth's crust which gives rise to "tilted" orographic blocks, such as the Sierra Nevada, takes place by a process of repetitive faulting, the faults being practically innumerable and the upthrow on each very small. This suggestion has not, so far as I am aware, been confirmed by field observation, but a similar one is discussed if not advocated by Woodworth[5] in his account of the post-glacial faults of eastern New York. While recognizing that the faulting might be due to a movement which would steepen the dip of the bedding or cleavage of the slates without changing the general attitude of the surface affected, he nevertheless emphasizes and gives support to the view that such repetitive faulting does in reality change the general surface profile. Thus, speaking of the Defreestville locality, he adds the throws of the various faults and says, "Within 11.67 feet the downthrow equals 13 inches. This rate of deformation, if carried out over a belt of country one mile wide, would produce a difference of level at one end of the line as regards the other equal to 493 feet." At Copake he estimates similarly the deformation of the surface at the rate of 336.7 feet in the mile, and in general he correlates the post-glacial faulting, in part at least, with the warping of New England. "The change of level or the so-called tilting of the land in and about the New England district since the retreat of the Wisconsin ice sheet has been accompanied by the fracture of rocks in certain zones of structure presumably so disposed as to yield to stress by small repetitive faults." I have no desire to combat this interesting generalization, but if the view that I have above expressed in a tentative way as to the origin of these faults is correct the faulting would not affect the profile of the surface in

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[5] *Op. cit.*

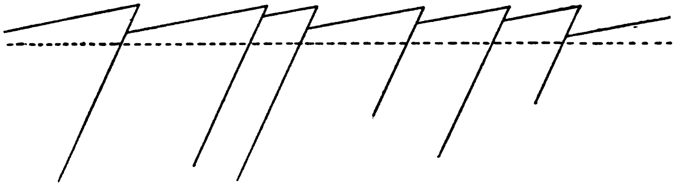


Fig. 1—Effect of slipping of parallel slabs by rotation induced by increase of volume. The net result of the expansion is a slight addition to the height of the surface without deformation of its general profile.

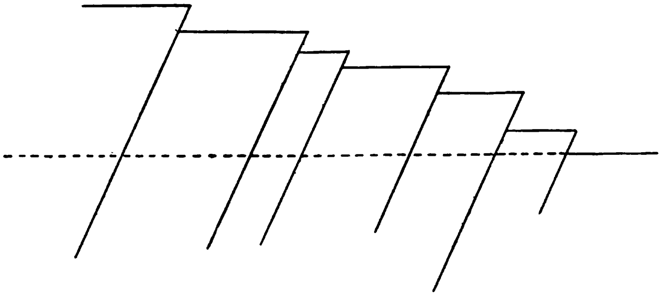


Fig. 2—Effect of faulting where each hanging-wall slab is moved parallel to itself over each foot-wall slab, resulting in an important deformation of the surface profile.

the way supposed. Woodworth's interpretation of the geomorphic effect of the faulting involves the idea that every hanging-wall block has been pushed up parallel to the fault planes relatively to every footwall block. But the same effect might be produced by a slight rotation of the blocks upon axes parallel to the strike at very moderate depths in consequence of a steepening of the dip under horizontal stress. In this case we would have a slight elevation of the region but no apparent tilting. The two interpretations have thus strongly contrasted consequences from a geomorphic point of view. It would seem possible, moreover, to determine observationally in favorable exposures which of the two interpretations is correct. On a horizontal glaciated surface if the faulting be due to rotation under horizontal compression, then the top of each block will be tilted downward toward the footwall side as in Fig. 1, while if the blocks are successively overthrust parallel to the fault planes and so modify the general profile of the surface, the tops of the blocks will not be so tilted but remain parallel to their original position as in Fig. 2. From what I have seen of these faults it appears to me that the difference in the two cases might be determined instrumentally, though I regret to say such measurement did not occur to me in the field while examining the faults near Banning.

OTTAWA, October 17, 1911.

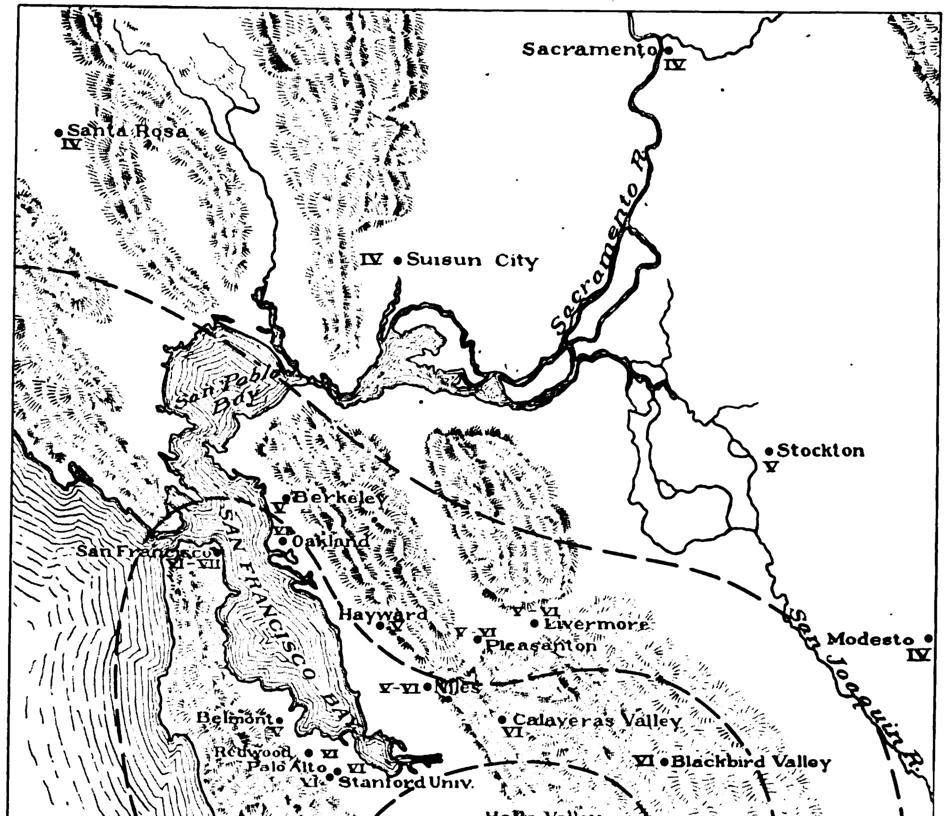
THE CENTRAL CALIFORNIA EARTHQUAKE OF JULY 1, 1911

By E. C. Templeton

Central California was disturbed on the afternoon of July 1, 1911, by the most severe earthquake shock experienced in this section of the country since that of April 18, 1906. While this earthquake is not to be compared to that of 1906 in the amount of damage done, nor in degree of violence, still it was an unusually strong shock, and probably more severe than the public generally supposes. It was felt over an area whose maximum dimension is about four hundred miles, embracing Los Angeles, where it was felt by a few persons in the highest buildings, and Sacramento, where it was quite generally felt. The shock was most severe in the San Francisco Bay region, and had a maximum intensity of between VIII and IX on the Rossi-Forel scale.

The earthquake came without preliminary tremor at 2:00:02.5 p.m., Pacific standard time. This is the time recorded at Lick Observatory on Mt. Hamilton, and is the earliest reliable time reported for the shock. The times reported from San Francisco, Oakland, and Berkeley show fair agreement, and indicate that the beginning of the shock was from ten to thirty seconds later than at Mt. Hamilton. The perceptible shock consisted of two rather distinct periods of vibration, of which the first, with a duration of between five and eight seconds, was the more intense. After a lull of about five seconds came the second period of vibration, with a duration of about five seconds. The shock was accompanied by a dull, rumbling sound, described as similar to the roar of a distant railway train, the sound preceding the shock by two or three seconds. This sound was heard pretty generally throughout the area having an intensity of VI or more, but apparently by only a small percentage of the people, as it was not loud enough to be heard above many common noises, or above the din of a busy town or city.

A considerable amount of data relative to the effects and intensities of the earthquake at different localities, has been collected. This includes reports from the seismographic stations at Lick Observatory on Mt. Hamilton, Berkeley, Oakland, Los Gatos, Santa Clara, and



Isoseismals of the California earthquake of July 1, 1911. Rossi-Forel scale.

San Jose, all of which, with the exception of the last mentioned, have been published,* together with a number of other reports on the effects and intensity of the shock. The remainder of the data has been furnished, either directly or indirectly, by persons who experienced the shock, and is based on their personal observations and sensations. In general, the different reports from any one locality have shown a pretty fair agreement as far as their indication of intensity is concerned, and the conclusions drawn from them should be very nearly correct. In attempting to determine what the intensity of the shock was at any locality, care has been taken to judge by its effects on structures, furniture, bric-a-brac, clocks, etc., rather than by the personal feelings and sensations of the observer.

The accompanying map shows the result of an attempted correlation, based on intensity, of the localities from which sufficient data have been collected to warrant an attempt at classification. The isoseismals show approximately the distribution of intensities.

The maximum intensity occurred in the vicinity of Coyote, a small town built on the alluvial floor of Santa Clara Valley, twelve miles southeast of San Jose. The intensity throughout the hills between Coyote and Mt. Hamilton, while apparently not as great as it was near Coyote itself, was the greatest reached at any place where the immediately underlying formation does not consist of unconsolidated, filled-in material. The time of the shock at Lick Observatory on Mt. Hamilton is the earliest reliable time reported. Coupled with the fact that the earthquake materially increased the flow of several streams near Mt. Hamilton, these facts seem to indicate that the epicenter was in the region between Coyote and Mt. Hamilton. The movement probably occurred at a considerable depth, with the displacement entirely taken up by the overlying material, leaving no trace or rift on the surface.

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* *Bul. Seismological Soc. of America*, I, pp. 110-121, 1911.

AN EARTHQUAKE IN TRINIDAD, B. W. I.

By ROBERT ANDERSON

About 10:45 p.m., local Trinidad time, on October 11, 1911, an earthquake was observed at Port-of-Spain on the Island of Trinidad. There were two shocks of four or five seconds duration with an interval of two or three seconds; the second shock was a little longer and a little stronger than the first. It was generally observed by persons awake; windows rattled, and the shock was startling, but there was no damage; intensity IV R. F. No accompanying sound was heard. The shock was felt also thirty miles south of Port-of-Spain.

On October 17th I visited the largest mud or gas "volcano" in Trinidad, which is situated on the Columbia Estate at the southwest tip of the island, fifty miles southwest of Port-of-Spain. It was evident that a gas outburst had occurred there but a few days previously, causing a large quantity of mud to be thrown out. Whether or not this had any connection with the earthquake I do not know, but it is conceivable that such an eruption of gas might either cause an earth tremor or be induced by one. Small quantities of gas are constantly issuing from the numerous vents of natural gas in Trinidad, but explosive eruptions such as this occur only at considerable intervals, usually a number of years apart, in several of the larger mud cones that are built up around these vents. On November 4th a cone of mud was thrown up as an island in a shallow portion of the sea off the south coast of Trinidad by an outburst of gas of considerably greater magnitude than the recent one of the Columbia volcano. I was not there at the time but in the reports obtained about it no mention is made of any accompanying tremor of the earth. Trinidad displays no true volcanic activity and contains no volcanic rocks. It is subject to frequent earthquakes.

WASHINGTON, D. C., December 12, 1911.

EARTHQUAKES IN HAYTI

April 12 to October 10, 1911

By J. **Scherer** x

April 12. *Anse-à-Veau,* 4 a.m. Shock observed by many persons.

May 5. *Port-au-Prince,* 5:50 p.m. Observed by many; preceded by noise; duration 2 seconds; intensity II.

Gauthier, 5:50 p.m. Preceded by noise; duration 2 seconds.

June 13. *Port-au-Prince,* 8:50:15 p.m. Duration 2 seconds; intensity II.

Port-Beudet, 8:50 p.m.

Bainet, about 9 p.m. Strong shock felt generally in the mountains.

June 17. *Cayes,* 10 p.m. Two shocks awakened some sleepers; intensity II.

Sept. 7. *Tiburon,* 11:45 a.m. One rather strong shock disturbing furniture and houses; it was preceded a few seconds by a feeble shock.

Oct. 4. *Gonaives,* 5:20 p.m. Shock felt by many; intensity II.

Oct. 6. *Port-au-Prince,* 5:28:30 a.m. A very strong shock preceded by a rumbling noise lasting about one minute. Trees swayed, many clocks were stopped, the ground moved like a rolling ship, some walls were cracked from top to bottom, and persons standing kept their feet with difficulty. This shock was more violent than that of April 3, 1910, and was nearly as strong as the one of September 23, 1887. Intensity VI.

Many shocks followed during the day, but the intensities of these after-shocks varied between II and III.

It is very probable that this shock was felt generally throughout the Republic, but as communication is slow more details will be given later.

x Professor Scherer writes me that the time is local mean time, Long. of the Station $4^h 49^m 21.4^s$. Green.

EFFECTIVE COOPERATION

It is the purpose of the Seismological Society of America to be useful, but in order to be useful it needs coöperation in the gathering of data regarding earthquakes.

Many of the engineering enterprises of the country, and especially those of the Pacific coast, are, of a necessity, directly concerned with earthquake phenomena. The society, therefore, confidently expects the coöoperation of engineers and of engineering enterprises in the Pacific coast states in the gathering of earthquake data.

The following letter from the construction engineer of the Spring Valley Water Company of San Francisco, is the first offer of coöperation the society has thus far received from such organizations in this part of the country. We hope to receive many others of a similar kind.

SPRING VALLEY WATER COMPANY,
SAN FRANCISCO, CAL.,

November 24, 1911.

DR. J. C. BRANNER,
Stanford University, California.

DEAR SIR:

In appreciation of the great importance of the work undertaken by the Seismological Society of America, of which you are the President, and for the purpose of coöperating therewith, instructions have been issued whereby reports regarding earthquakes will be received from the following places within the property of the Spring Valley Water Company:—

Milbrae
Crystal Springs Cottage
San Andreas Cottage
Pilarcitos Cottage
Newark Slough
Sunol
Arroyo Valle
Pleasanton
Calaveras
Lake Merced Cottage
University Mound Cottage
Francisco Street Reservoir
City Office, San Francisco

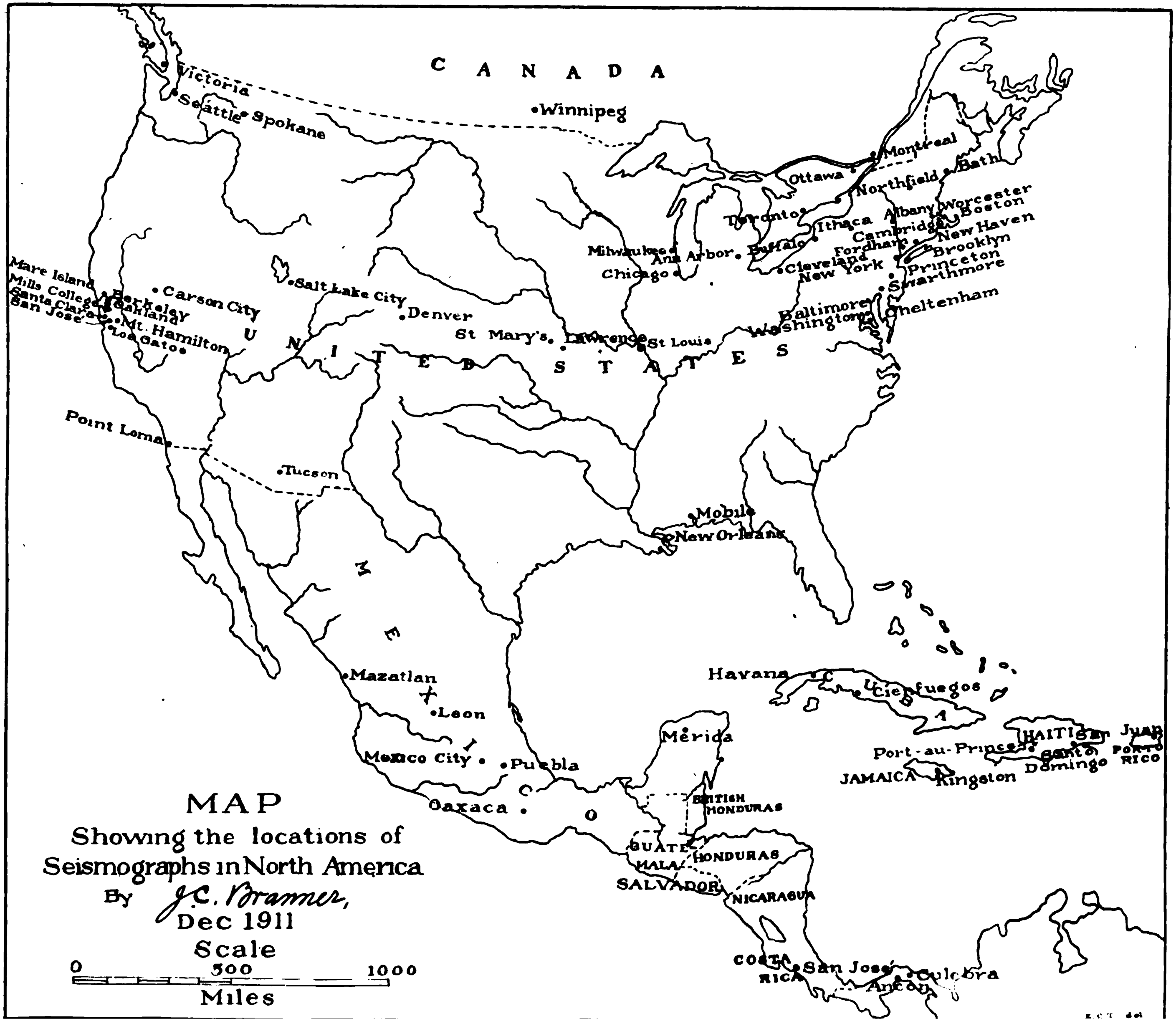
Upon receipt of these reports copies of the same will be forwarded to your Society. I am enclosing a copy of these instructions and report blanks.

If there are any other data that you wish in connection with this study please let me know and I will gladly furnish whatever we may have in the matter.

Yours very truly,
F. C. HERRMANN.

MR. SAYLES' GIFT

THE DIRECTORS OF THE SEISMOLOGICAL SOCIETY TAKE THIS OPPORTUNITY TO ANNOUNCE THE RECEIPT OF $5000, THE GIFT OF MR. ROBERT WILÇOX SAYLES, (HARVARD, A. B. 1901), A MEMBER OF THIS SOCIETY, WHICH SUM, BY THE TERMS OF THE GIFT, MAY BE USED AT THE DISCRETION OF THE BOARD OF DIRECTORS FOR PUBLISHING THE *BULLETIN*. THIS GENEROUS FINANCIAL CONTRIBUTION ASSURES THE MAINTENANCE OF PUBLICATION BY THE SOCIETY ON A SUBSTANTIAL BASIS, AND IS A MOST WELCOME AND TIMELY ENDOWMENT OF SEISMOLOGY IN AMERICA. MR. SAYLES IS A GEOLOGIST IN CHARGE OF THE GEOLOGICAL SECTION OF THE UNIVERSITY MUSEUM AT HARVARD UNIVERSITY, CAMBRIDGE, MASS., AND IS ALREADY KNOWN TO MANY OF OUR MEMBERS AS A CONTRIBUTOR TO THE SUBJECT OF EARTHQUAKE FREQUENCY IN RELATION TO CLIMATIC CYCLES. THE SOCIETY CAN PERHAPS BEST SHOW ITS GRATITUDE FOR THIS GENEROUS ASSISTANCE IN THE FIRST YEAR OF ITS WORK OF PUBLICATION BY RENDERING ITS *BULLETIN*, THROUGH THE PAPERS AND COMMUNICATIONS SUBMITTED BY ITS MEMBERS, THE MEDIUM OF PROMOTING EVERY PHASE OF THE SCIENCE OF EARTHQUAKES, AND THROUGH THIS MEANS THE WELFARE OF AMERICA.



MAP
Showing the locations of
Seismographs in North America
By J. C. Branner,
Dec 1911

LIST OF SEISMOGRAPHS IN AMERICA.

[Note.—Anyone who knows of a seismograph in operation or about to be installed anywhere in America, and not mentioned in this list, is requested to report it to the Secretary of the Seismological Society of America, Stanford University, California.]

NORTH AMERICA

CANADA

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
McGill University	Montreal	(Not working)	Ewing duplex
Dominion Observatory	Ottawa	Dr. Otto J. Klotz	Bosch
St. Boniface Col. (S.J.)	Winnipeg	O. Rousseau	Wiechert 80 k.
University of Toronto	Toronto	Dr. R. F. Stupart	Grey-Milne
Meteorological Office	Victoria, B.C.	E. B. Reed	Grey-Milne
Grand Trunk	Prince Rupert, B. C.	(Not yet installed)	Milne

MEXICO.

Servicio Seismologico Nacional, Dr. José G. Augilera, Director	Tacubaya, D. F.	F. Patiño y Ordaz	Wiechert hor. 1700 k.
		H. Camacho	Wiechert vert. 1300 k.
		M. Muñoz Lumbier	Wiechert hor. 1000 k.
		A. Pastor y Giraud	Wiechert hor. 200 and 125 k.
		R. M. Tello	Schmidt Gravimeter Bosch-Omori phot. Wiechert vert. 80 k.
Servicio Seis., Station of first order	Merida, Yuc.		Wiechert vert. 1300 k. Wiechert hor. 1000 k.
Servicio Seis., Station of second order	Mazatlan, Sin.	T. Casas	Wiechert vert. 80 k. Wiechert hor. 200 k.
Servicio Seis., Station of second order	Oaxaca, Oax.	J. M. Ortega	Wiechert hor. 200 k. Wiechert vert. 80 k.
Observatorio Meteorologico Central	Mexico, D. F.	Ing. M. E. Pastrana	Poëy pend.
Collegio del Estado	Puebla	F. de P. Tenorio	Milne Contreras
Observatorio	Leon, G'to.	Prof. M. Leal	?

COSTA RICA

Instituto Fisico Geografico	San Jose	P. Biolley	Ewing Duplex pend.
Calegio Superior de Señoritas	San Jose	Prof. J. F. Tristan	Trifilar pend
Private	Alajuela	H. Cots	

PANAMA

Gatun Observatory Ancon Observatory	Culebra, C. Z.	Third Div., Chief Engineer, Isthmian Canal Comm.	Bosch-Omori 100 k. Bosch-Omori 25 k.

UNITED STATES

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
ALABAMA			
Spring Hill Col. (S. J.)	Mobile	Rev. Cy. Kuhlmann	Wiechert 80 k.
ALASKA			
U. S. Coast and Geodetic Survey	Sitka	F. L. Adams	2 Bosch-Omori
ARIZONA			
U. S. Coast and Geodetic Survey	Tucson	L. W. Weed	2 Bosch-Omori
CALIFORNIA			
Lick Observatory	Mt. Hamilton	W. W. Campbell	Ewing duplex and 3-comp.
U. S. Naval Observatory	Mare Island	T. J. J. See	Bosch-Omori
Mills College	Mills College		Ewing duplex
University of California	Berkeley	Prof. A. C. Lawson	Wiechert 80 k. 2 Bosch-Omori 100 k. Omori tromometer Marvin
Santa Clara Col. (S. J.)	Santa Clara	Rev. J. S. Ricard	Wiechert and vert. 80 k.
Chabot Observatory	Oakland	C. Burckhalter	Ewing duplex
Private	Los Gatos	I. H. Snyder	Original duplex
University of the Pacific	San Jose	Prof. Louis S. Kroeck	Ewing duplex
Raja Yoga Academy	Point Loma	F. J. Dick	West
COLORADO			
Sacred Heart Col. (S. J.)	Denver	Rev. Wm. Forstall	Wiechert 80 k.
CONNECTICUT			
Yale University	New Haven	(Not working)	Bosch-Omori 100 k.
DISTRICT OF COLUMBIA			
Georgetown University Observatory (S. J.)	Washington	Rev. F. A. Tondorf	Wiechert and vert. 80 k.
Weather Bureau	Washington	Prof. C. F. Marvin	2 Bosch-Omori
HAWAII			
Magnetic Obs. Station, U.S. Coast and Geod. Survey	Honolulu	O. H. Gaarden	Milne E.-W. hor.
ILLINOIS			
St. Ignatius Col. (S. J.)	Chicago	(Not yet installed)	Wiechert 80 k.
KANSAS			
University of Kansas	Lawrence	H. P. Cady	
St. Mary's College (S.J.)	St. Mary's	(Not yet installed)	Wiechert 80 k.
LOUISIANA			
Loyola College (S. J.)	New Orleans	Rev. A. L. Kunkel	Wiechert 80 k. and vert.
MAINE			
Private	Bath	L. S. Metcalf	Omori 22 k.
MARYLAND			
Johns Hopkins University	Baltimore	Prof. H. F. Reid	Milne and Bosch-Omori
Magnetic Obs. Station U.S. Coast and Geod. Survey	Cheltenham	J. E. Burbank	2 Bosch-Omori, 100 k.

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
MASSACHUSETTS			
Harvard University	Cambridge	Prof. J. B. Woodworth	2 Bosch-Omori, 100 k.
Massachusetts Institute of Technology	Boston	Prof. T. A. Jagger, Jr.	2 Bosch-Omori
Holy Cross Col. (S. J.)	Worcester	L. J. Haubert	Wiechert 80 k.
MICHIGAN			
Detroit Observatory, University of Michigan	Ann Arbor	Prof. W. J. Hussey	2 Bosch-Omori 100 k. Wiechert hor. and vert, 100 k.
MISSOURI			
St. Louis University (S.J.)	St. Louis	Rev. J. B. Goesse	Wiechert 80 k.
NEVADA			
Private	Carson City	(Not operating)	Ewing duplex
NEW JERSEY			
Princeton University	Princeton	Prof. W. B. Scott	?
NEW YORK			
N. Y. State Museum	Albany	Dr. J. M. Clarke	2 Bosch-Omori
Canisius College (S. J.)	Buffalo	W. C. Repetti	Wiechert 80 k.
Jesuit College (S. J.)	Brooklyn	J. Glover	Wiechert 80 k.
Fordham Univ. (S. J.)	Fordham	Rev. E. P. Tirnan	Wiechert 80 k.
Cornell University	Ithaca	Prof. R. S. Tarr	Bosch-Omori 25 k.
N. Y. Acad. Sciences	New York	Dr. E. O. Hovey	Mainka
OHIO			
St. Ignatius College (S.J.)	Cleveland	Rev. F. L. Odenbach	Wiechert hor. and electric 80 k.
PENNSYLVANIA			
Swarthmore College	Swarthmore	Prof. John A. Miller	Milne
UTAH			
University of Utah	Salt Lake City	Prof. F. J. Pack	Bosch-Omori
VERMONT			
Norwich University	Northfield	Prof. Wm. A. Shaw	(not installed)
WASHINGTON			
University of Washington	University Sta., Seattle	Prof. H. Landes	Bosch-Omori 25 k.
Gonzaga College (S. J.)	Spokane	Rev. E. M. Bacigalupi	Wiechert 80 k.
WISCONSIN			
Marquette Univ. (S. J.)	Milwaukee	Rev. J. L. McGeary	Wiechert 80 k.

WEST INDIES

College St. Martial	Port-au-Prince Haiti	J. Scherer	Pendulum
Estacion Meteorologica Seminario	Santo Domingo	R. Padre Bourdon	?
Magnetic Obs. Station, U. S. Coast and Geod. Survey	Porto Rico	George Hartnell	2 Bosch-Omori
Department of Agriculture	Trinidad	P. Carmody	Milne
	Kingston, Jamaica	J. F. Brennan	Verbeck Gray-Milne
CUBA			
College of Belen (S. J.)	Havana	Rev. G. L. Gangoili	Vicentini
	Cienfuegos	Rev. S. Sarasola	

SOUTH AMERICA

BRAZIL

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
Observatorio Astronomico	Rio de Janeiro	Dr. H. Morize	Bosch-Omori 15 k. Wiechert 110 k.

PERU

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
	Arequipa		Milne

ARGENTINA**

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
Observatorio Magnetico	Pilar	W. G. Davis	Milne
Observatorio Astronomico	La Plata	W. J. Hussey	Vicintini
Oficina Meteorologica	Mendoza		
Oficina Meteorologica	Cordoba		

CHILE*

INSTITUTION	POST-OFFICE	IN CHARGE	SEISMOGRAPH
Seismological Service of Chile — Count Montessus de Ballore, Director	Santiago		Bosch-Omori; Wiechert hor. and vert.; and Stiattesi hor.
Second order	Tacna		Wiechert hor., 200 k.
	Copiapo		Wiechert hor., 200 k.
	Osorno		Wiechert hor., 200 k.
	Punta Arenas		Wiechert hor., 200 k.

The following stations of the third order are furnished with Agemennone seismoscopes:

1. Angol
2. Antofagasta
3. Calama
4. Castro
5. Cauquenas
6. Chillan
7. Concepcion
8. Constitucion
9. Evanjelista Island
10. Illapel
11. Iquique
12. Juan Fernandez Island
13. Lebu
14. Mocha Island
15. Ovalle
16. Puerto Montt
17. Punta Dungeness
18. Quillota
19. San Fernandez
20. San Filipe
21. Serena
22. Talca
23. Taltal
24. Tarapaca
25. Temuco
26. Toco
27. Valdivia
28. Vallenar
29. Valparaiso

(*The information regarding the stations in Chile is taken from the statement of the director, M. Montessus de Ballore, given in the Boletin del Servicio Sismolojico de Chile, vol. I, Santiago, 1909.)

** In addition to these, instruments have been ordered for stations in the provinces of Salta, Catamarca, and Santa Cruz.

SEISMOLOGICAL NOTES

Rubber stamps for labeling seismograms.—At the earthquake station of Harvard University, Cambridge, Mass., the appearance of the smoked-paper seismograms has been greatly improved by replacing the handwritten memoranda by stereotype headings imprinted by rubber stamps. The stamps remove the soot and leave a white lettering which takes readily in blue-printing copies. The stamps are applied before fixing the records. The following stamps are employed: In the middle of the seismogram at top, "Harvard Seismographic Station, Cambridge, Mass., U. S. A." In the middle below, "75th Meridian Time, West. Station clock......s. fast; ....s. slow." The error of the station clock, if any, is inserted in its appropriate place before fixing. In the upper left-hand corner, "Seismic Record No.........," the number to be filled in corresponding with the number in the Record of Earthquakes kept at the station. In the upper left and lower left-hand corners the words "North" and "South" are stamped, showing the orientation of the paper for that component, and so for the east-west component. Also in the upper left-hand corner to the right of the component designation is printed "100 kg. Bosch-Omori Tromometer," showing the type of seismograph to which the record pertains. Beneath these words is given the date of the beginning of the record, and in the lower left-hand corner is printed the date of the closing of the record. A stamp, "Artificial disturbance," with an arrow, is used to point out any known artificial portion of the record, such as is caused by entering the instrument room, testing period of pendulums, etc. The stamps giving the dates and the components are printed before the records are put in place; the others are added after removing the paper, when it can be placed flat. Other stamps might be employed for numbering five-minute intervals of the lines of minute ticks. It is found that the use of the stamps considerably reduces the time taken to put the smoked-paper record into shape for filing away in the archives of the station.

J. B. W.

Mr. G. M. Flint of the Harvard seismographic station has produced a good fixative for smoked-paper records, composed of: best wood alcohol shellac, 1¼ oz.; denatured alcohol, 1 quart.

The earthquake in Germany.—An earthquake of unusual strength was felt on November 16th at about 9:25 p.m. (Greenwich mean time) in the south of Germany, throughout Switzerland, and in the east of France and the north of Italy. It was followed by two others of less importance early on November 17th, one shortly after midnight, the other at about 3 a.m. The reports so far available in this country are singularly meagre. There does not seem to have been any loss of life; but slight damage to property occurred in several places, such as Constance, Stuttgart, Freiburg, Mülhausen, and Hechingen, and, though it is difficult to credit the statement, at Munich. Leaving the last-named place out of account, the area of slight damage is about 140 miles long from east-northeast to west-southwest, and 90 miles wide, and contains about 10,000 square miles. The centre may have been about 10 miles to the north of Schaffhausen. The shock was felt so far as Dresden, 310 miles from this point, so that the disturbed area may have contained as much as 300,000 square miles. It is thus probable that the focus was situated at some depth. The vibrations were recorded at several distant observatories—in this country at Shide and West Bromwich. At Heidelberg, Besançon, and Potsdam the recording levers were deranged or broken.—*Nature,* Nov. 23, 1911, p. 117.

From Rio de Janeiro, Brazil.—Dr. Henrique Morize, Director of the National Observatory at Rio de Janeiro, sends the following items in regard to the seismologic equipment at that station: We now have in operation one pair of 15 kilo Bosch-Omori horizontal pendulums that have been working since 1905, and one inverted Wiechert pendulum of 100 kilos that has been in operation since 1909. A vertical Wiechert seismograph was installed in 1909, but it has worked only irregularly. This region is, as you know, very quiet seismologically, and the nearest earthquakes registered here, come, for the most part, from the Andes or from Argentina.

Our installation is still defective on account of a lack of room, and one new model Mainka seismograph still remains to be mounted. Fortunately, on account of the serious difficulties with which we have had to deal for so many years, the government has finallly decided to have the observatory moved to a place where there is plenty of room and to have a proper building erected. I trust that inside of a year we shall be in the new quarters.

How an earthquake feels at sea.—The following graphic descriptions of the sensations produced by earthquakes felt on board of vessels are kindly furnished by Professor McAdie.

U. S. S. SOUTH DAKOTA,
NAVY YARD, MARE ISLAND, CAL.,
July 10, 1911.

PROFESSOR ALEXANDER G. MCADIE,
San Francisco, Calif.

SIR:

. . . On July 1, 1911, the U. S. S. South Dakota, under my command, was en route to Mare Island from sea, having entered the Golden Gate about 1:30 p.m. About 2 p.m. (the exact time was not noted on board) when in the channel between Angel and Alcatraz islands, a very decided jar or shock was felt by all on board. I was on the bridge at the time and, although confident that the ship was in deep water, I was alarmed, as the sensation was what one would expect if a ship should strike a rock. The navigator hurried to the end of the bridge and, after looking at the water alongside, informed me that the ship's headway was not checked; he was therefore impressed the same as I was with the idea that we had struck bottom.

I then telephoned the engine room to ask if anything had happened there, thinking it possible that the breaking of a main shaft or crank might jar the ship in the manner we had felt. I was informed that nothing was wrong in the engine room. Several minutes later I learned through the medium of the wireless telegraph office on board that there had been an earthquake.

I note in your letter that you say we should have felt a series of "bumps" on board the ship. What we did feel was quite different. There was only one jar, and that not in the nature of a "bump," but a very decided and severe shock, like striking bottom or running at good speed into a wall or another vessel. In seeking for a cause I had almost decided in my mind that we had struck a sunken wreck hard when I was relieved to learn that there had been an earthquake. No disturbance of the water accompanied the phenomenon, nor were any atmospheric peculiarities noticeable.

Very respectfully,

F. M. BENNETT,
Captain, U. S. Navy.

COAST AND GEODETIC SURVEY,
SAN FRANCISCO, CAL.,
July 14th, 1911.

PROF. ALEXANDER MCADIE,
San Francisco, Calif.

DEAR PROFESSOR:

Thanks for sending me Captain Bennett's letter about the recent earthquake. I am able to supplement that information by relating an experience of my own on the U. S. schooner Marcy, lying at anchor in three fathoms of water off Eureka, Humboldt Bay, during an earthquake in the summer of 1872.

We were at work in the ward room, drafting, at the time. The noise and feeling to me was as if a heavy barrel was being rolled along the deck we stood on.

Very respectfully,
FERDINAND WESTDAHL,
Assistant.

Slight shock in southern California.—At 6:57 p.m., November 21, a slight earthquake occurred at San Bernardino, lasting not more than five seconds, possibly not more than three. I should judge the intensity to have been IV of the Rossi-Forrel scale. Objects on shelves were slightly shaken and water in pitchers plainly showed the vibrations. To me the shock appeared to come from a southwesterly direction. It was sudden, without any perceptible preliminary tremor, nor was any after-shock noted. There were no unusual atmospheric conditions: the weather was fine and dry. The shock is said to have been more distinct near the mountains. This is interesting on account of the existence of faults in that region. The newspapers report that the shock was also felt at Redlands, Rialto, and Pomona.

GORDON SURR.

SAN BERNARDINO, CAL., November 22, 1911.

For the smoked-paper records of seismographs of the Bosch-Omori type there is an American paper known as "white coated litho" which answers the purpose very well. A ream of 480 sheets 24x44 inches will cut up with little waste into strips 15 cm. wide and 95 cm. long, giving 2,000 record strips, at a much lower cost than the imported article.

Microseisms at Santa Clara.—The Jesuit service at Santa Clara College, Santa Clara, California, in charge of Father Jerome S Ricard, sends us notices of the following microseisms observed at that station between September 29 and November 1, 1911.

The shocks are all classed as barely noticeable. Only the time of greatest motion and amplitude is here given. The time is mean civil Greenwich.

1911	h.	m.	s.	Amplitude, mm.
September 29	17	12	43	3.87
October 4	6	39	56	1.37
October 6	10	45	30	.75
October 10	13	41	12	1
October 14	17	04	24	1
October 15	east-west agitation			
October 17	21	25	38	1.5
October 18	19	13	56	.75
October 20	18	21	55	trace
October 29	18	26		trace
November 1	9	49		trace

Death of Professor Davidson.—Professor George Davidson, honorary member of the Seismological Society of America, died at his home in San Francisco, December 1, 1911, at the age of eighty-seven. Professor Davidson was a man of great activity and broad interests. He was for many years in charge of the work of the U. S. Coast and Geodetic Survey on the Pacific coast. In 1898 he was appointed professor of geography in the University of California, and held that position until 1905, when he was made professor emeritus. He was one of the foremost scientific men of America, one of the founders of the Seismological Society of America, and its first president.

Types of seismographs.—Many inquiries reach us from persons who contemplate installing seismographs regarding the different types of instruments, prices, etc. For the benefit of all who are or may become interested in this matter, Professor Harry Fielding Reid, of Johns Hopkins University, is preparing an article that will appear in the next number of the Bulletin of the Seismological Society of America.

The new seismologic service of Costa Rica.—We take great pleasure in announcing the establishment of the new seismologic service of Costa Rica. The excellent work already done in that part of Central America and the seismicity of the region covered by the service give promise of valuable results. The following letter from Professor Tristan, the Secretary, to whom seismologists are already greatly indebted, is self-explanatory:

SAN JOSÉ, COSTA RICA,
November 3, 1911.

TO THE SECRETARY OF THE SEISMOLOGICAL SOCIETY OF AMERICA,
Stanford University, Cal.

DEAR SIR:

I have the honor to inform you that on the 21st of October last there was established in this capital a "Centro de Estudios Sismologicos" the principal purpose of which is to record and to collect all data relating to seismic phenomena in Costa Rica and in other Central American republics.

Yours respectfully,
J. FID. TRISTAN, *Secretary.*

The California earthquake near Tasmania.—Professor George Davidson sends this note regarding an earthquake observed southwest of Tasmania at the time of the great California earthquake of April 18, 1906. On July 31, 1906, Professor W. D. Alexander obtained at Honolulu the following item copied from the log of the French ship "Andre Thadon":

"Mercredi 18 Avril, 1906, latitude 45° 40′ S., longitude 141° 21′ (E. de Paris), 3 h. 21 m. p.m. une secousse de tremblement de terre ou une eruption volcanique sous-marine, d'une durée de 45 secondes environ. La navire a été ebranlé dans toutes ses parties."

Professor Davidson adds that the position mentioned is about 300 geographic miles southwest by west from South Cape, Tasmania, and that the great circle distance between San Francisco and the place mentioned is 7100 geographic miles.

Earthquakes in geographic literature.—According to Col. C. F. Close, president of the Geographical Section of the British Association, five per cent of the papers in the Proceedings of the Royal Geographical Society of London treat of volcanoes and earthquakes.

Engineers and earthquakes.—One of the members of the Seismological Society, in speaking of the needs of the engineering profession in the earthquake regions, remarks:—"Mr. Blank (one of our best engineers) I understand has joined the Society, and, like many engineers, is interested in the possible effects of earthquakes on the great reclamation dams now being put up in the arid regions. These men want to know the seismicity of given places. The Lord help them!"

If the engineers of the country will cooperate with the Seismological Society of America in the effort to gather and publish data regarding earthquakes, the Seismological Society of America will gladly undertake to get them some help here on this earth. These same engineers should remember, however, that we cannot invent information. They should remember, also, that every observation they make upon earthquakes is an item of value and a contribution to the very information they want.

Slight Shock at Point Loma, Cal.—Mr. Frederick J. Dick, member of the Seismological Society of America, sends us the following notes:—"A shock having an intensity of IV R.F. scale was felt at the meteorological station, Raja Yoga Academy, Point Loma, Cal., at 11:10 a.m., Pacific time, on October 18, 1911. It lasted only about two seconds, and was recorded on a C.D. West seismoscope with an east-west movement of 2½ millimeters, and a north-south movement of 1½ millimeters. No noise was observed and no alarm was caused. The shock was noticed only by persons in or near buildings where windows were rattled." This earthquake was recorded by the seismographs at the seismographic station at Santa Clara College, Calif.

A late Mexican earthquake.—An earthquake is reported to have been felt over a large part of Mexico at 12:40 p.m. on December 16. It is said to have reached an intensity of VIII or IX in the state of Guerrero, and a few buildings are said to have fallen in Chilpanzingo, a town 120 miles southwest of Mexico. In the city of Mexico there was considerable alarm, and some adobe walls were thrown down.

Southwestern Alaska.—The newspapers report a severe earthquake on the southwestern Alaskan coast on October 17, 1911. It is said to have lasted several seconds, and to have affected the glaciers considerably.

Slight shock at Pasadena, Cal.—Mr. J. S. Rossiter, member of the Seismological Society of America, observed a slight shock at Pasadena, California, November 1, 1911, at 9:54:30, Pacific standard time. The shock lasted from three to five seconds, and had an intensity of II or more R.F. scale. Mr. Rossiter notes that it was accompanied, or possibly preceded by a sound as of a breeze, and that doors creaked and a pianola was audibly affected. A slight shock was recorded the same day at the Santa Clara College station, Santa Clara, Cal.

At Los Gatos, Calif.—Mr. Irving H. Snyder reports a shock at Los Gatos, Cal., October 15, about 5:45 a.m., with an intensity between II and III, and another October 17, 1911, at 1:25 p.m., with an intensity between II and III R.F. scale. Some persons noted a low roar at the time of the second disturbance. The shock of October 17 is reported to have been noticed by a few persons at San Jose and at Stanford University, California.

Shock at Bellingham and Victoria.—The newspapers report an earthquake on September 28, 1911, at about 6:45 p.m. No damage was reported at Victoria, B. C., but at Bellingham, Wash., it is said that a few frail chimneys were thrown down.

Where a station clock is employed with an electric contact every minute, the current strong enough to work the magnets of the time tickers of the seismographic drums may, by sparking at the contact in the clock, produce an excessive wear of the poles and a stopping of the clock. This trouble may be reduced by working the clock on a separate circuit, with a single cell dry battery, wired to a relay which in turn closes the main circuit.

REVIEWS

A. Alfaro, G. Michaud, P. Biolley.—Informe Sobre el Terremoto de Toro Amarillo. Boletin de Fomento, Anno i, No. 7. San José, Costa Rica, Agosto, 1911, pp. 533-539.

This paper is an official report of the committee appointed by the government to investigate the effects of an earthquake that occurred August 28, at Toro Amarillo in the canton of Grecia. The shock was felt at San José, where it had an intensity of VI, and was recorded by Professor Tristan's seismograph at the Colegio Superior de Señoritas. This record is given in the report at page 534, showing a movement confined almost entirely to a northwest-southeast direction. Twenty kilometers northeast of San José at Alajuela the intensity was VII, and at Grecia, twenty kilometers further to the northeast, the intensity was VIII. It is noted that even with this intensity there was very little damage done at Grecia, owing to the fact that the church was built of iron and the houses of wood. Further north, at an elevation of 1419 metres above tide, the committee began to find landslides and cracks in the earth. After passing El Portillo they found the road completely blocked by landslides and uprooted trees. At Toro Amarillo the intensity was X, and houses were thrown down, trees uprooted, the ground was much cracked, and there were more than sixty landslides in the hilly part of the country in the immediate neighborhood.

The intensity seems to have been greater north of the mountains than to the south. The committee are of the opinion that the epicenter was from six to nine kilometers to the northwest of the volcano Poás, and that the center is not deep.

Another short article by D. A. Alfaro, published in the periodical *Paginas Illustradas* for September 24, 1911, under the title "Buenas construcciones," gives some of the observations of the committee upon the buildings of the region. He points out with good reason that methods of construction that are best adapted to the earthquake regions of Italy, Jamaica, Japan, and California, are out of the question in the interior of Costa Rica. He also calls timely attention to the disadvantages of the ordinary earthen tiles so extensively used for covering the houses in that country. Such tiles are heavy and more or less dangerous in an earthquake region. He recommends instead the use of corrugated iron, which, though necessarily imported, is not expensive, is comparatively light, and may be so used as to strengthen the buildings, instead of overloading and weakening them as the tiles do.

J. C. B.

SEISMOLOGY IN ST. LOUIS UNIVERSITY. Published under the direction of JOHN B. GOESSE, S. J., Director, and GEORGE E. RUEPPEL, S. J., Assistant. Vol. VII, No. 5, of the BULLETIN OF ST. LOUIS UNIVERSITY. St. Louis, December, 1911.

This number of the Bulletin of St. Louis University, fifty-three pages, is devoted exclusively to seismology. It is full of interest to the seismologist, and especially to those who wish to familiarize themselves with the methods and modern development of the science. It has an additional individual interest on account of its giving the historical outlines of the development and organization of the system of seismologic stations in North America under the control of the Society of Jesus. It shows also that the Society of Jesus has in addition a large number of seismologic stations in all parts of the globe.

One chapter is devoted to the physics of the seismograph; then follow a table for determining distances of shocks, and a table of coordinates for St. Louis, explanations of the symbols of the Göttingen nomenclature and a table of records of the St. Louis University station for the year 1910.

The seismologic number of this Bulletin is a valuable contribution to seismology in this country, and it does great credit to the institution under the auspices of which it is issued.

J. C. B.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE SEISMOLOGICAL SOCIETY OF AMERICA, NOVEMBER 3, 1911.

The meeting was called to order by President Branner at 4:30 p.m., in Room 1404, Merchants' Exchange Building, San Francisco. Directors Branner, Burckhalter, Lawson, Louderback, McAdie, and Townley were present, and director See was represented by proxy.

The minutes of the meeting of the Board held on September 16th were approved as printed in BULLETIN No. 3.

The following action was taken by the directors:

The resignation of one member was accepted.

Thirty-seven new members, whose names are subjoined hereto, were recommended by the president and secretary, and elected to membership in the Society. Ten institutions were placed on the list of subscribers to the BULLETIN.

The list of members of the Society was ordered printed in the December number of the BULLETIN.

The secretary was instructed to send copies of the BULLETIN to various scientific journals.

President Branner read a letter from Mr. Robert W. Sayles, of Chestnut Hill, Mass., a member of the Society, offering a gift of $5000.00 to be used as a Publication Fund during the next five years. The generous gift was accepted with expressions of gratitude and hearty appreciation on the part of the directors.

A committeee of three, with power to act, consisting of Directors Branner, Lawson and Woodworth, was appointed to confer with Mr. Sayles concerning the use and distribution of the fund provided by him.

Director Lawson then offered the following resolution, which was unanimously adopted:

Resolved:—That it is the sense of the Board of Directors of the Seismological Society of America, representing the membership of the Society, that the maintenance and improvement of the BULLETIN of the Society is the very best means of furthering the purposes for which the Society was organized; there is a great need for such a means of communication among the members and for a medium of publication of investigations in seismology and allied branches of science.

The Board adjourned at 5:30 o'clock.

S. D. TOWNLEY, *Secretary*.

LIST OF MEMBERS ELECTED NOVEMBER 3, 1911

W. D. Alexander: Honolulu, T. H.
Charles P. Berkey: New York, N. Y.
Mrs. Chas. D. Blaney: Saratoga, Cal.
Barnabas Bryan: Bingham, Utah.
Albert Burch: San Francisco.
Arthur W. Burgren: Minillas, Zacatecas, Mex.
J. C. Cebrian: San Francisco, Cal.
T. C. Chamberlin: Chicago, Ill.
Frank V. Cornish: San Francisco, Cal.
José Costa: San Francisco, Cal.
Chas. S. Cushing: San Francisco, Cal.
Edwin Duryea, Jr.: Palo Alto, Cal.
Lewis, Alden Estes: Detroit, Mich.
John R. Freeman: Providence, R. I.
Chas. N. Gould: Norman, Oklahoma.
John S. Grasty: University of Virginia, Va.
F. C. Herrmann: San Francisco, Cal.
J. S. Hook: Stanford University, Cal.
Mrs. Lou Henry Hoover: London, England.
E. P. Jennings: Salt Lake City, Utah.
V. L. Kellogg: Stanford University, Cal.
George F. Kunz: New York, N. Y.
Adolph Lietz: San Francisco, Cal.
J. D. Maddrill: Ukiah, Cal.
J. K. Moffitt: San Francisco, Cal.
Wm. Mulholland: Los Angeles, Cal.
Wm. F. Prouty: University, Ala.
Chester A. Reeds: Bryn Mawr, Pa.
Francisco Dias da Rocha: Ceará, Brazil.
C. F. Runyon: San Francisco, Cal.
Pearl G. Sheldon: Ithaca, N. Y.
Peter Soo-Hoo: San Rafael, Cal.
George Otis Spencer: Chicago, Ill.
Donald Steel: Kanshassa, Congo Belge, Africa.
Gordon Surr: San Bernardino, Cal.
R. B. Symington: San Francisco, Cal.
C. F. Tolman, Jr.: Tucson, Arizona.

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December 29, 1911

Adams, Frank D. ....McGill University, Montreal, Canada
Adams, Maxwell 29 West 9th St., Reno, Nev.
Addicott, James Edward ....1831 Peters Ave., New Orleans, La.
Aguilera, José G. 6a Ciprés No. 176, Mexico, D. F.
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Alexander, W. D. ....Box 732, Honolulu, T. H.
Alfaro, Anastasio San José, Costa Rica
Anderson, Robert Van Vleck....U. S. Geol. Surv., Washington, D. C.
Arango, Ricardo M. Panama, R. P.
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Bain, H. Foster 420 Market St., San Francisco, Cal.
Baird, B. A. ....1300 Laguna St., San Francisco, Cal.
Ballard, C. A. State Normal School, Moorhead, Minn.
de Ballore, Count de Montessus..Servicio Sismolojico, Santiago, Chile
Barbour, Edwin H. University of Nebraska, Lincoln, Neb.
Bard, Darsie C. ......Montana State School of Mines, Butte, Mon.
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Blain, J. (S. J.) ..St. Boniface College, St. Boniface, Manitoba, Can.
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*Branner, J. C. Stanford University, Cal.
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Brown, L. V. W. ....Riverside, Cal.
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Bryan, William Lowe ....Bloomington, Ind.
Buckner, Chas. 719 Elizabeth St., San Francisco, Cal.
Buhne, H. H. ....Eureka, Cal.
Burbank, Luther Santa Rosa, Cal.

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* Life Member

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Burckhalter, Chas. Chabot Observatory, Oakland, Cal.
Burgren, Arthur W. ....Minillas, Zac., Mexico
Butler, G. Montague Colorado School of Mines, Golden, Colo.
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Church, J. E., Jr. ....Reno, Nev.
Cirera, Ricardo (S. J.) Tortosa, Spain
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Clark, V. V. 444 Henry Bldg., Seattle, Wash.
Clark, W. O. ....State Normal School, Milwaukee, Wis.
Clemans, Carl Snohomish, Wash.
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Collom, Roy E. ....Box 957, Coalinga, Cal.
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Crothers, Geo. E. ....Chronicle Bldg., San Francisco, Cal.
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Derleth, C., Jr. University of California, Berkeley, Cal.
Dick, Frederick J. ....Point Loma, Cal.
Dole, A. R. Hammonton, Cal.
Dole, Chas. S. ....Lihue, Hawaii
Doolittle, C. L. Upper Darby, Pa.
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Durand, W. F. Stanford University, Cal.
Duryea, Edwin, Jr. ....308 Lincoln Ave., Palo Alto, Cal.
Dutton, C. E. Englewood, N. J.
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Eddy, A. J. ....2630 Fulton St., Berkeley, Cal.
Eells, Charles P. 2415 Pierce St., San Francisco, Cal.
Einarsson, Sturla ....Faculty Club, Berkeley, Cal.
Elder, James W. Petaluma, Cal.

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Estes, Lewis Alden Trussed Concrete Steel Co., Detroit, Mich.
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Finlay, George I. ....205 W. Uintah St., Colorado Springs, Colo.
Fisher, George J. Coyote, Cal.
Forbes, John F. ....Crocker Bldg., San Francisco, Cal.
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Fowler, F. H. ....221 Kingsley Ave., Palo Alto, Cal.
Franklin, E. C. Hygienic Laboratory, Public and Marine
Hospital Service, Washington, D. C.
Franklin, W. S. ....South Bethlehem, Pa.
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Freeman, John R. ....235 Arlington Ave., Providence, R. I.
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von Geldern, Otto ....1978 Broadway, San Francisco, Cal.
George, R. D. 845 11th St., Boulder, Colo.
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ROSSI-FOREL SCALE OF EARTHQUAKE INTENSITIES

I. **Microseismic shock**: recorded by a single seismograph or by seismographs of the same model, but not by several seismographs of different kinds; the shock felt by an experienced observer.

II. **Extremely feeble shock**: recorded by several seismographs of different kinds; felt by a small number of persons at rest.

III. **Very feeble shock**: felt by several persons at rest; strong enough for the direction or duration to be appreciable.

IV. **Feeble shock**: felt by persons in motion; disturbances of movable objects, doors, windows; creaking of ceilings.

V. **Shock of moderate intensity**: felt generally by everyone; disturbance of furniture, beds, etc., ringing of swinging bells.

VI. **Fairly strong shock**: general awakening of those asleep, general ringing of house bells; oscillation of chandeliers; stopping of pendulum clocks; visible agitation of trees and shrubs; some startled persons leave their dwellings.

VII. **Strong shock**: overthrow of movable objects; fall of plaster; ringing of church bells; general panic, without damage to buildings.

VIII. **Very strong shock**: fall of chimneys, cracks in walls of buildings.

IX. **Extremely strong shock**: partial or total destruction of some buildings.

X. **Shock of extreme intensity**: great disaster, buildings ruined, disturbance of the strata, fissures in the ground, rock-falls from mountains.

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